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AN INVESTIGATION OF METHODS FOR DETERMINING NOTCH ROOT STRESS F--ETC(U)

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1 OF 2

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

An Investigation of Methods for Determining Notch Root Stress from Far Field Strain in Notched Flat Plates

by

John Charles Garske

September 1977

Thesis Advisor: G.H. Lindsey

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

9

4. TITLE (and Subtitle)

6

An Investigation of Methods for Determining Notch Root Stress from Far Field Strain in Notched Flat Plates.

5. TYPE OF REPORT & PERIOD COVERED

Master's Thesis,
September 1977

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)

10

John Charles/Garske

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS

Naval Postgraduate School
Monterey, California 93940

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS

Naval Postgraduate School
Monterey, California 93940

11

12. REPORT DATE

Sep~~tember~~ 1977

13. NUMBER OF PAGES

99

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)

Naval Postgraduate School
Monterey, California 93940

12 99p.

15. SECURITY CLASS. (of this report)

Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Stress Concentration Factors
Finite Element Analysis
Notch Root Stress
Neuber's Equation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Notched flat plate specimens have been tested to examine Neuber's equation and other relations with respect to their application in the determination of stresses in the plastic range at the notch root when the far field strain is known. A nonlinear finite element solution has also been obtained for notched flat plates in plane stress to facilitate an evaluation of it as an analytical method for calculating the behavior of stresses at the notch root

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(Page 1) S/N 0102-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

251 450

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Experimental results indicate that Neuber's equation is ten to twenty-five percent in error for the notch geometry, strain level and material behavior encountered in the present study. Finite element analysis results were in close agreement with experimental results.

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An Investigation of Methods for Determining Notch Root Stress from Far Field Strain in Notched Flat Plates

by

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Lieutenant, United States Navy
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Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
September 1977

Author John Charles Garske
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Chairman, Department of Aeronautics

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Dean of Science and Engineering

ABSTRACT

Notched flat plate specimens have been tested to examine Neuber's equation and other relations with respect to their application in the determination of stresses in the plastic range at the notch root when the far field strain is known. A nonlinear finite element solution has also been obtained for notched flat plates in plane stress to facilitate an evaluation of it as an analytical method for calculating the behavior of stresses at the notch root.

Experimental results indicate that Neuber's equation is ten to twenty-five percent in error for the notch geometry, strain level and material behavior encountered in the present study. Finite element analysis results were in close agreement with experimental results.

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I. INTRODUCTION

A major goal of the Navy Aircraft Life Management Program is to reliably and accurately predict the fatigue life of aircraft structures. The method currently employed determines structural life as a function of known structural and material properties and of "g" loading, which is measured by accelerometers in each aircraft. Since loads carried by the aircraft structure for a given "g" load are also a function of variables such as airspeed, weight, altitude, angle of attack and stores distribution, all of which are not measured, the present method of estimating structural life, to be safe, per force must be conservative; thus, aircraft can not be employed at their optimum cost effectiveness.

In order to obtain a more accurate means of determining aircraft life, a fatigue monitoring system has been developed [Ref. 1]. This system provides a direct airborne capability for recording strains at critical locations in the structure through the use of strain gages. Placement of strain gages at a location of stress concentration is not practical for long term applications, because fatigue of the strain gage itself precludes the use of this method. Therefore, the strain gage must be located at a point on the structure near the site of interest but undisturbed by the effects of stress concentrations.

An accurate relationship between applied strain, or far field strain, and local stress behavior at a point of stress

concentration will, therefore, be necessary, if a strain monitoring system is to be a viable means of providing data for aircraft life monitoring. Calculating local stress for a known far field strain becomes complicated when the material in the area of the stress concentration is stressed beyond the elastic limit.

The theoretical solution to the nonlinear plasticity problem has been demonstrated for simple geometries; however, these solutions do not have a practical, wide application in aircraft geometries [Ref. 2]. As a consequence, the majority of the current literature has centered on using Neuber's relationship for finding stress at the edge of a hole. Neuber [Ref. 3] proposed that the geometric mean of the stress concentration factor, K_{σ}, and the strain concentration factor, K_{ε}, is equal to the elastic stress concentration factor, K_t. In equation form this is

$$K_t^2 = K_{\sigma} K_{\varepsilon}$$

where

$$K_{\sigma} = \frac{\text{local stress}}{\text{nominal stress}} = \frac{\sigma}{S}$$

and

$$K_{\varepsilon} = \frac{\text{local strain}}{\text{nominal strain}} = \frac{\varepsilon}{e}$$

Impellizzeri [Ref. 4] proposed a method of calculating local stress using Neuber's relationship, material properties, nominal strains and K_t; all of which are known quantities, since nominal strain is easily obtained from applied strain.

Although Neuber's relationship has had wide coverage in the available literature, the results of investigations have not been consistent. Crews [Ref. 5] found the relationship to be accurate within a factor of two. Griffis [Ref. 6] found the relationship to be in error by as much as twenty-five percent for a notched flat plate in plane stress. Horne [Ref. 7] found the relationship to be accurate within four percent for a flat plate with a circular hole in plane stress with up to one percent strain at the edge of the hole. From the above, it can be seen that more information is needed to evaluate the validity of Neuber's relationship.

In order to provide an accurate means for calculating local stress behavior from applied strain, the accuracy of Neuber's relationship in its application to flat plates in plane stress was tested during this investigation. Also, a nonlinear finite element analysis of plates in plane stress was compared with the results of material testing to provide an analytical means of evaluating local stress behavior. Additionally, a proposal for calculating local stress from applied strain was made for inclusion in reference 8.

II. NOTCHED FLAT PLATE SPECIMEN TESTS

A. INTRODUCTION

In view of the apparent discrepancy regarding the validity of Neuber's relation, tests were performed on notched flat plate specimens in plane stress to observe Neuber's relation and the relationship between far field strain and local stress behavior at the notch root. To insure uniformity, all flat plate specimens were manufactured from the same sheet of 0.090-inch thick 7075-T6 aluminum. In addition, all specimens were oriented the same direction on the original sheet of material and each plate was manufactured to fit a common loading fixture used in the Riehle testing machine.

In all phases of specimen testing, strain gages were connected to a Wheatstone bridge circuit, which has been calibrated for strain gage factor and temperature considerations. The output of each Wheatstone bridge was measured by a digital voltmeter and recorded on a stripchart recorder. An event marker on the stripchart recorder was used to coordinate the load with the strain gage trace. The load was recorded by hand at convenient increments.

B. UNIAXIAL TENSILE STRESS-STRAIN TESTS

To determine the stress-strain characteristics of the test plates, two flat plate uniaxial specimens were tested in plane stress.

1. Description of Procedure

The first specimen was tested to accurately determine the stress-strain relationship in the elastic range. Loads were applied, held, and strains were read on the digital voltmeter until creep in the specimen became significant. The second specimen was used to investigate the stress-strain relationship in the region of large strains. During this test, the load was applied at a constant rate and strain data were recorded simultaneously on the stripchart recorder. Figure 1 shows the instrumentation used to record strain data.

2. Test Results

For both specimens, stress was calculated from load data for a corresponding level of recorded strain. The results of the tests were combined to produce the stress-strain relationship for the test specimen material. Table 1 of Appendix A and Figure 2 contain the results of the uniaxial tensile stress-strain test.

From test results, the modulus of elasticity for the test material was determined to be 10575 ksi, and the yield stress was determined to be 75 ksi.

C. NOTCHED PLATE SPECIMEN TESTS

Notched flat plate specimens were tested in plane stress to investigate Neuber's relation and the relationship between far field strain and stress at the notch root. Four specimens with different notch geometries were utilized in the test. Figure 3 describes the four plate geometries and strain gage placement.

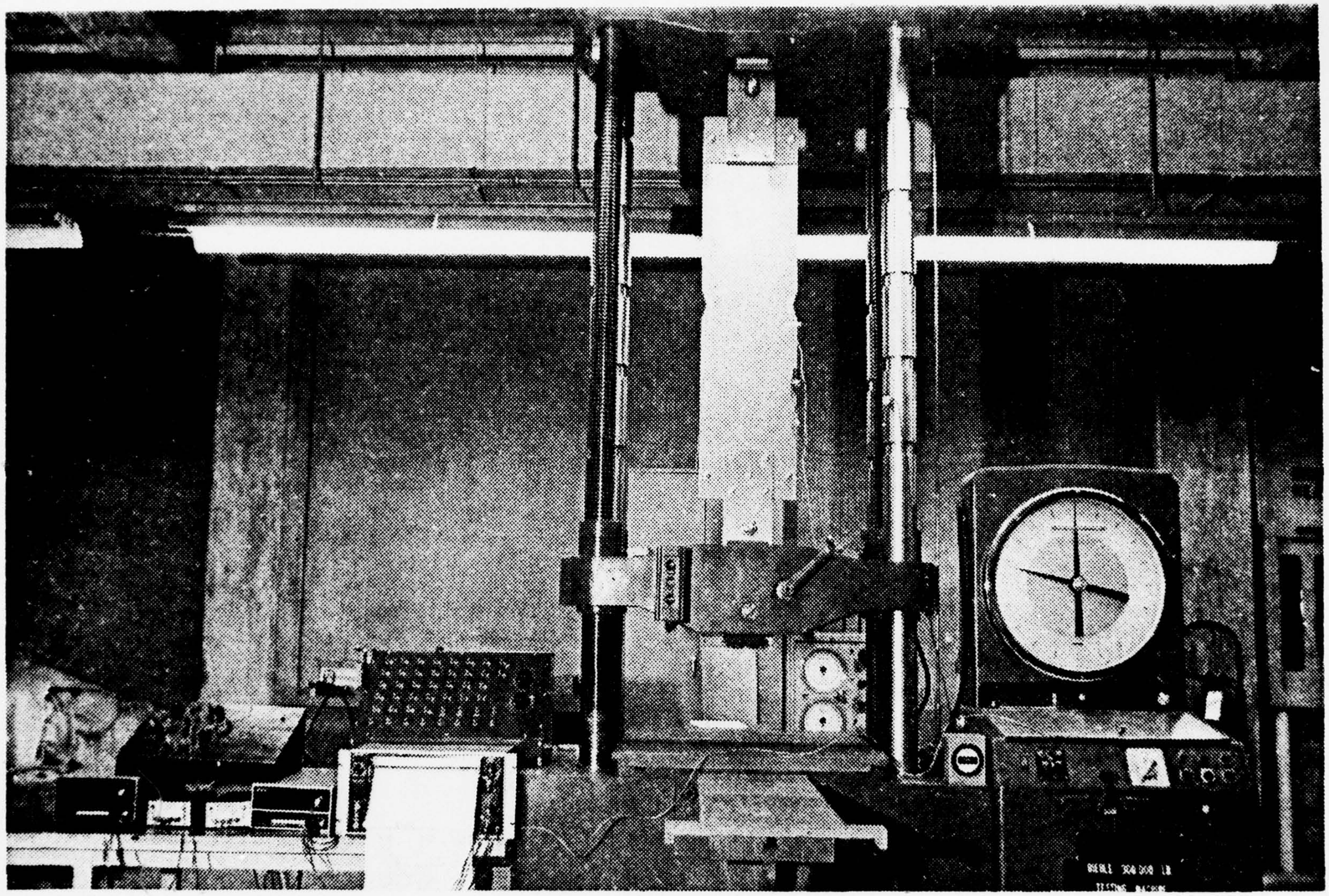


Figure 1 Photograph of Test Equipment

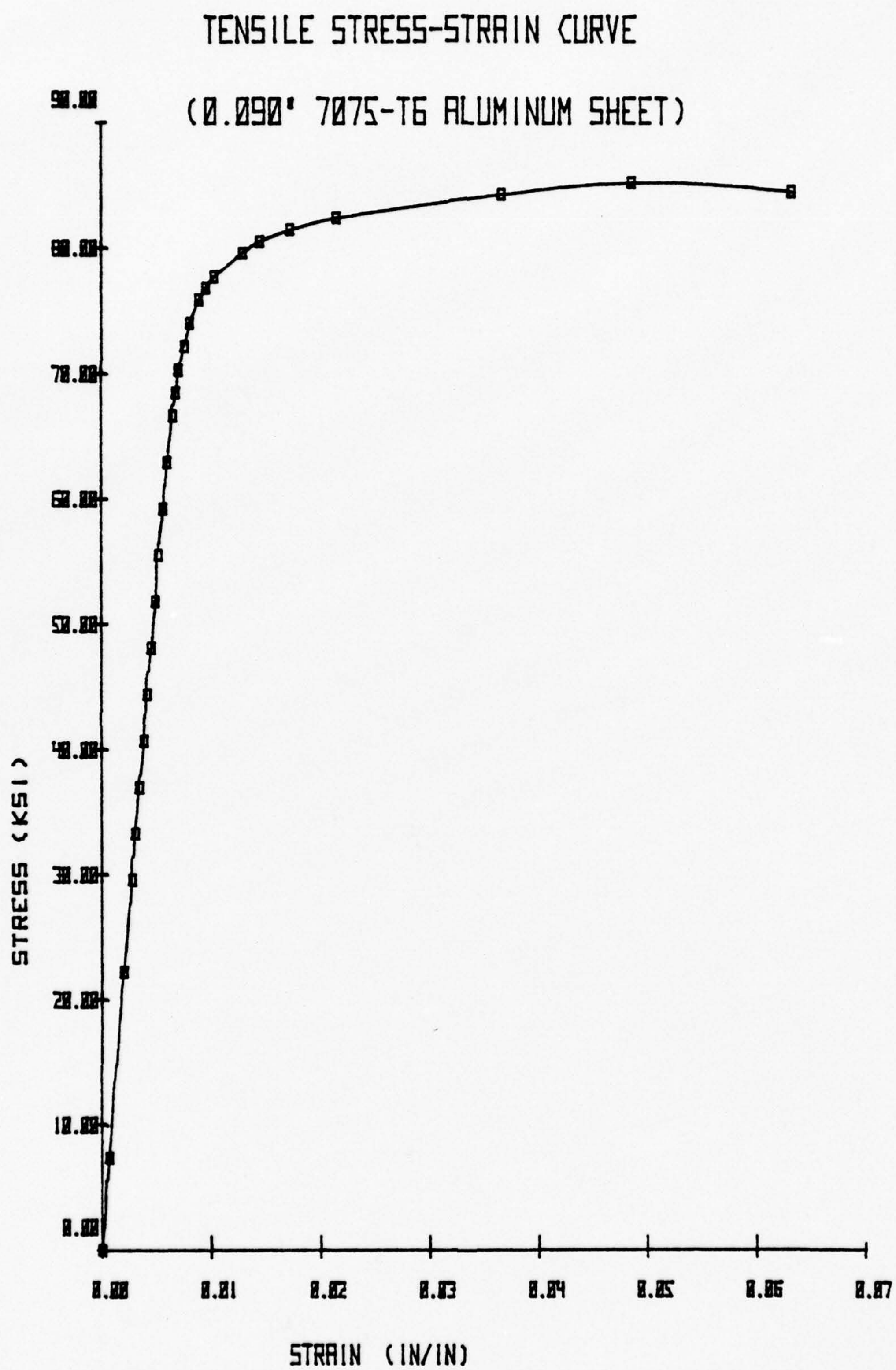
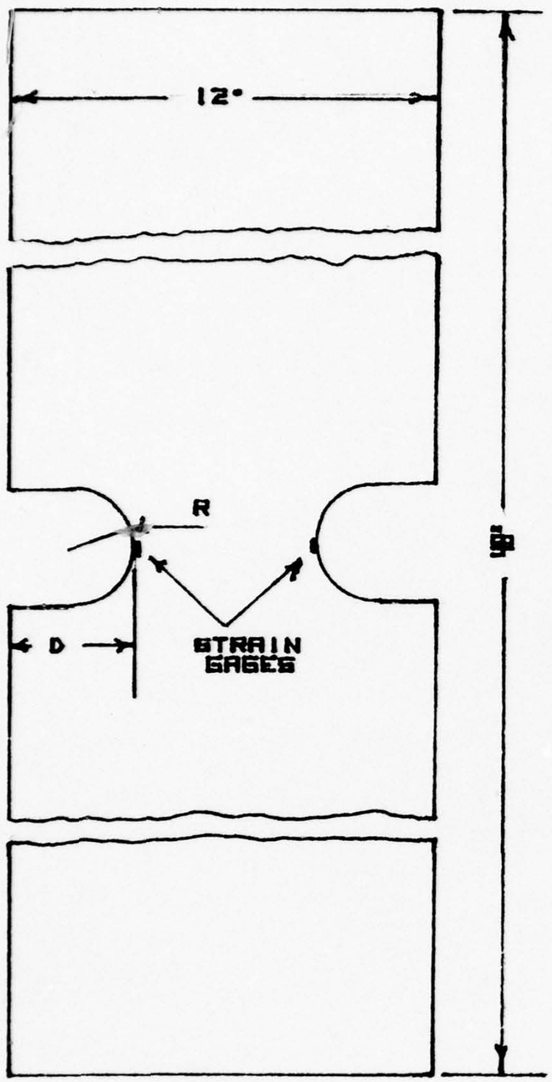

TENSILE STRESS-STRAIN CURVE
(0.090" 7075-T6 ALUMINUM SHEET)
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
STRESS (KSI)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
STRAIN (IN/IN)

FIGURE 2



DESCRIPTION OF NOTCHED TEST SPECIMENS

	SPECIMEN NUMBER			
	1	2	3	4
NOTCH DEPTH –D	1.7"	1.7"	1.0"	0.5"
NOTCH ROOT CURVATURE –R	0.5"	1.0"	1.0"	3.0"

NOTES

STRAIN GAGE TYPE: MICHRO-MEASUREMENTS EA-130250BG-120

STRAIN GAGE SIZE: 0.125"

STRAIN GAGE RANGE: 3%

STRAIN GAGE LOCATION: CENTER OF GAGE LOCATED 0.070" FROM TIP OF NOTCH ROOT

FIGURE 3

In addition to the strain gages shown in Figure 3, an extensometer was placed in the region of far field strain. Strain data from the extensometer were recorded by the Riehle testing machine as the machine recorder produced a graph of applied load versus extensometer strain.

1. Test Procedure

The instrumented specimens were loaded by the Riehle testing machine with a constantly increasing tensile load. Figure 4 shows test specimen number four mounted in the machine. As the load was applied, strain data were recorded in a manner similar to that described for the uniaxial tensile stress-strain tests.

The tests were terminated for plate number one when the gage limit of three percent was exceeded; for plates two and three after both gages had failed; and for plate four when the load limit of the loading fixture holding the specimen was reached.

2. Test Results

To analyze stress and strain behavior at the notch root, the data recorded at the notch roots were averaged. To determine stress from strain data, the data obtained in the uniaxial tensile specimen tests were used in a regression scheme that calculated a stress for any given strain. Far field stresses and strains and nominal stresses and strains were calculated from a knowledge of the load, plate geometry and modulus of elasticity of the test material.

Tabular data from the notched specimen tests are presented in Tables 2 to 27 of Appendix A. In the tables of

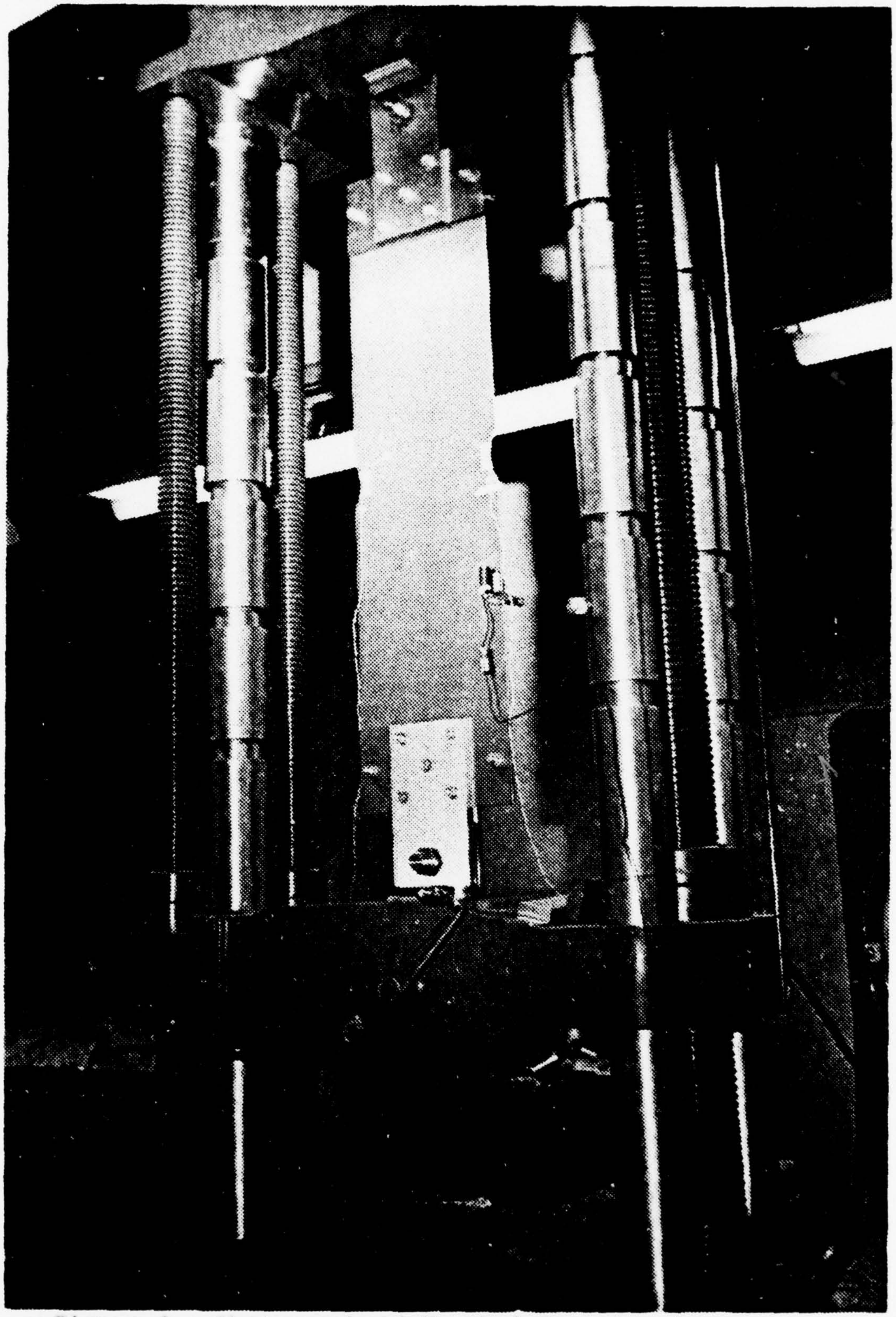


Figure 4. Photograph of Notched Test Specimen

Appendix A, stresses 1 and 2 and strains 1 and 2 refer to stresses and strains at the notch roots. Stress and strain number 3 refer to extensometer data. It can be seen that strains 1 and 2 are in disagreement by 10 percent for plate number 1 (Table 2). This is attributed to strain gage locations not being identical on both notches and the rapidly changing stress gradients in the notch root area of plate number 1. As the notches became less severe, the differences between notch root strain gage readings became less. The notch root strains recorded for plate number four are almost identical. Figures 5-8 contain a graphical presentation of far field stress and strain concentration factors versus notch root strain for plates 1 thru 4, respectively. Far field stress concentration factors have been defined as the ratio of notch root stress to far field stress. The far field strain concentration factor has been defined similarly.

The experimentally determined elastic far field stress concentration factors for the notched test specimens were as follows:

Notched Plate Number	Elastic Far Field Stress Concentration Factor
1	3.60
2	3.23
3	2.45
4	1.65

The far field elastic stress concentration factor can be related to the traditional elastic stress concentration factor by the ratio of the far field area to the nominal area, which

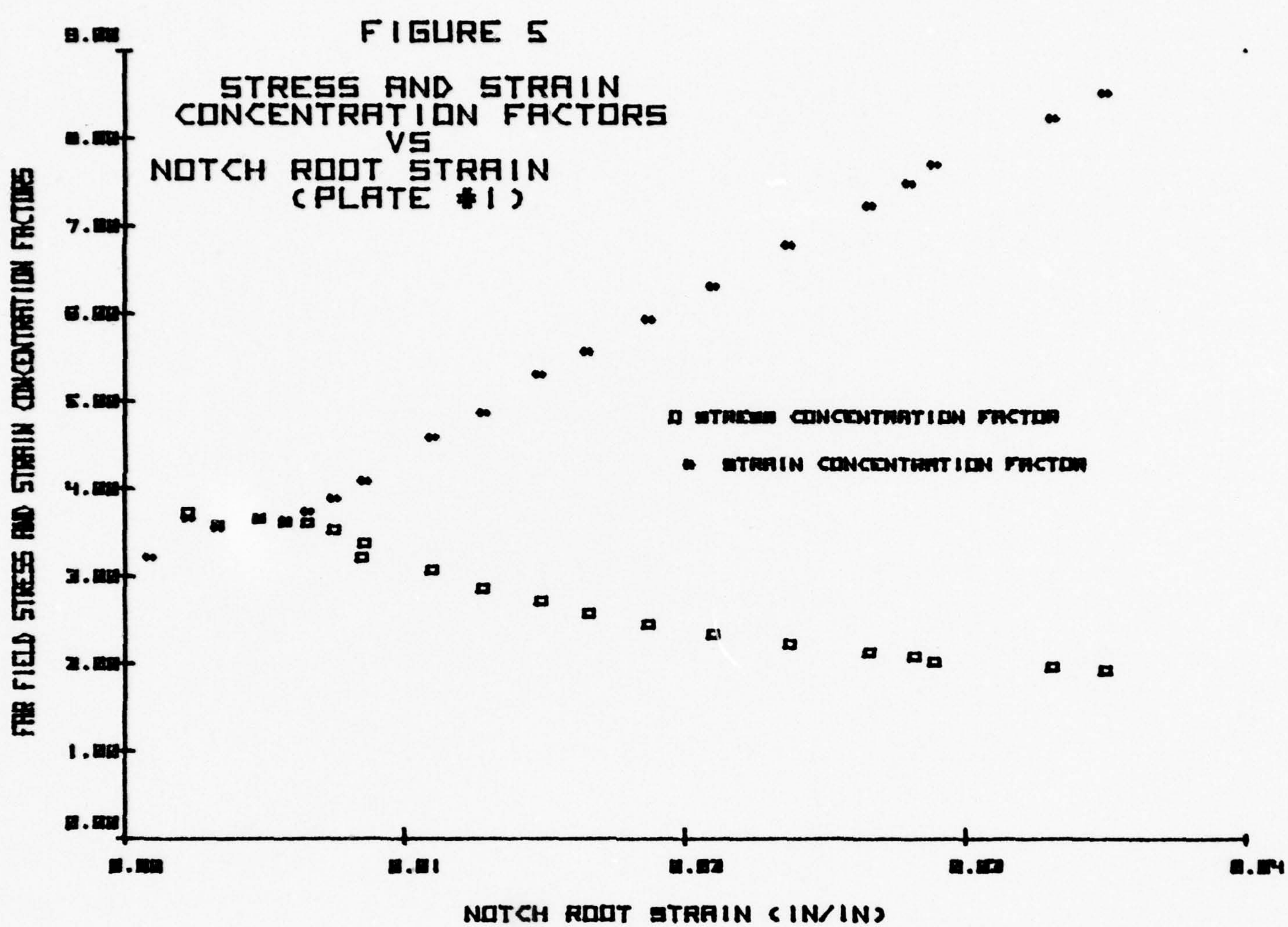


FIGURE 5

STRESS AND STRAIN CONCENTRATION FACTORS VS NOTCH ROOT STRAIN (PLATE #1)

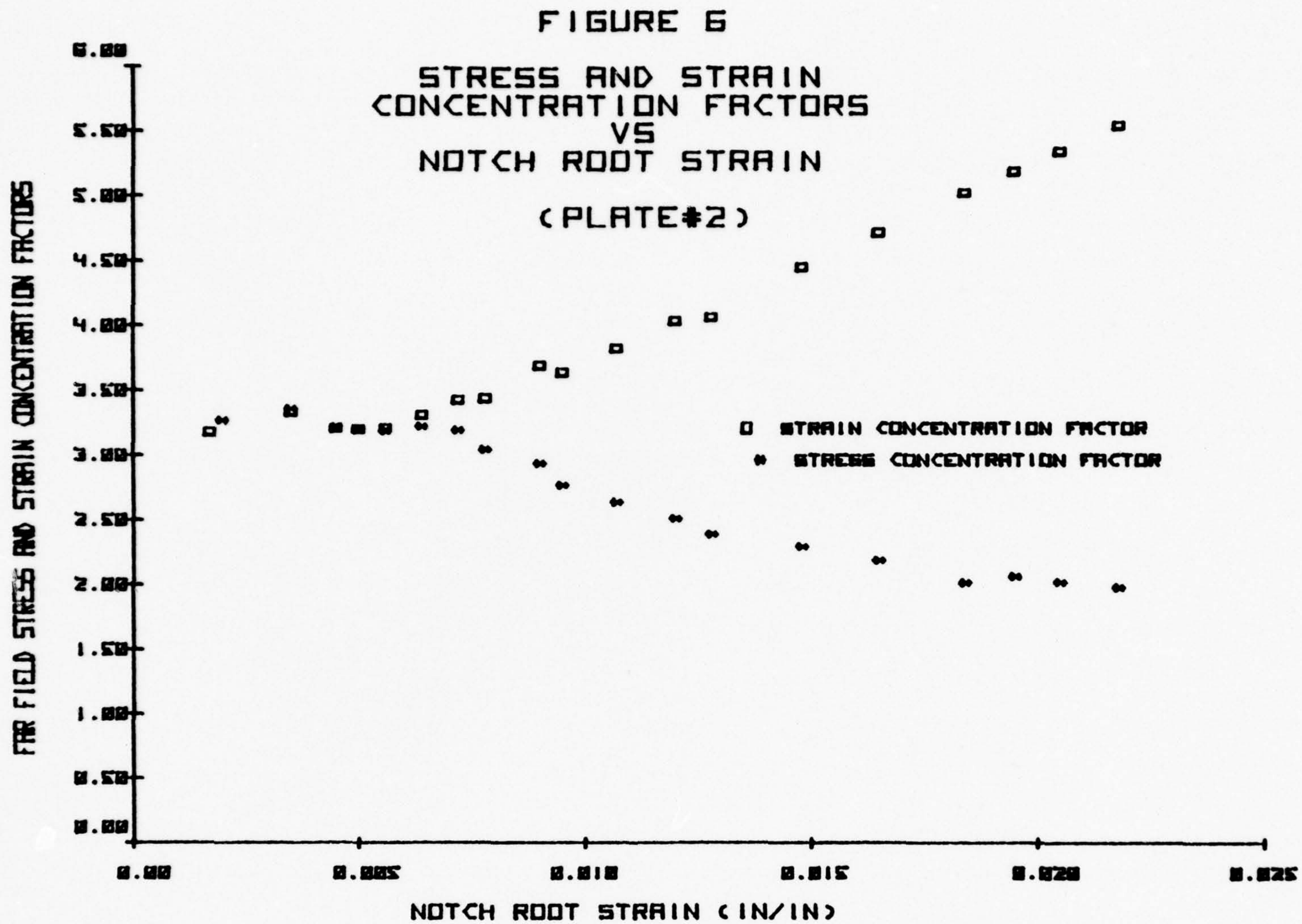


FIGURE 6
STRESS AND STRAIN
CONCENTRATION FACTORS
VS
NOTCH ROOT STRAIN
(PLATE#2)
STRAIN CONCENTRATION FACTOR
STRESS CONCENTRATION FACTOR
FAR FIELD STRESS AND STRAIN CONCENTRATION FACTORS
6.00
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0.00
0.005
0.010
0.015
0.020
0.025
NOTCH ROOT STRAIN (IN/IN)

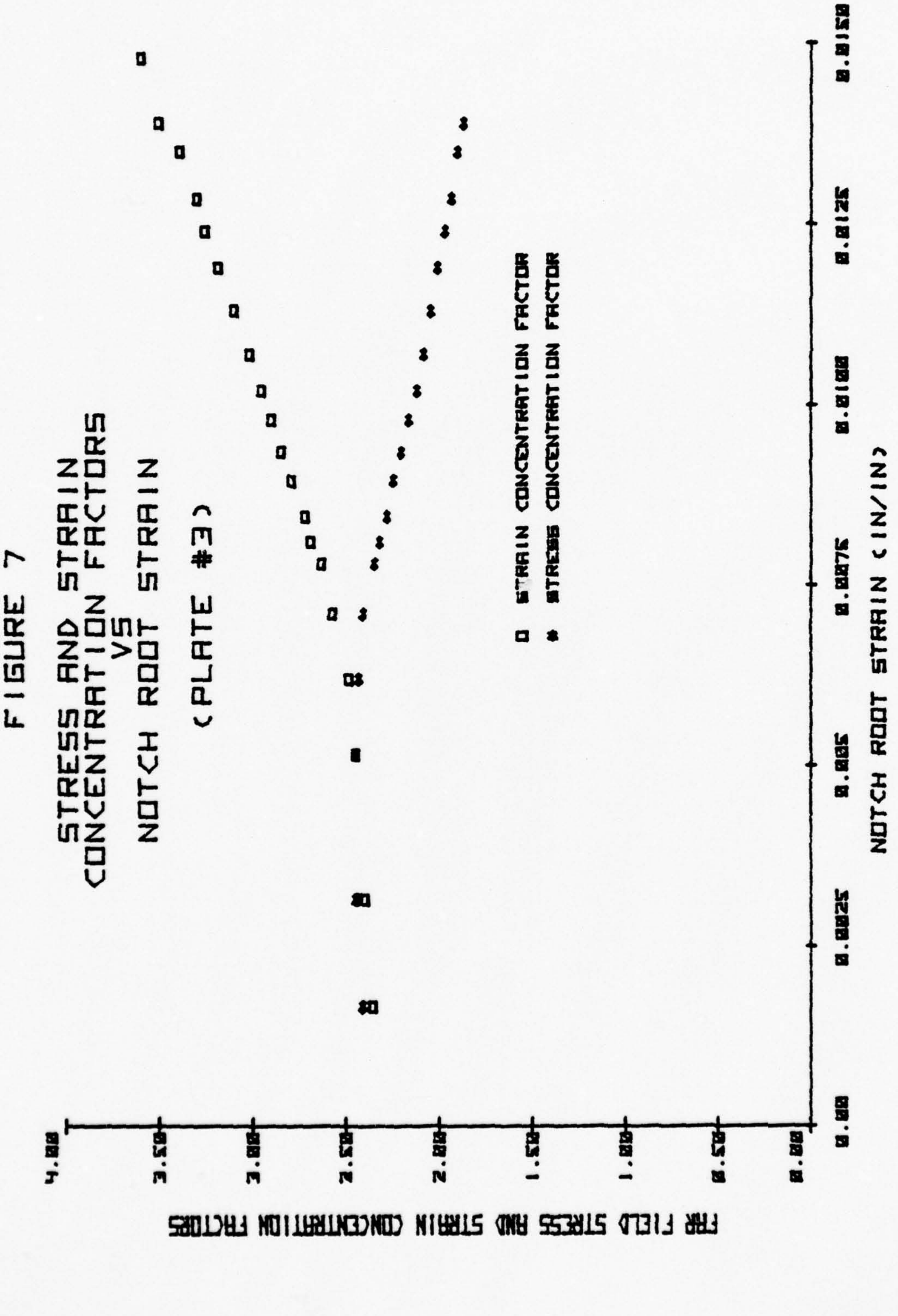


FIGURE 7
STRESS AND STRAIN
CONCENTRATION FACTORS
VS
NOTCH ROOT STRAIN
(PLATE #3)
STRAIN CONCENTRATION FACTOR
STRESS CONCENTRATION FACTOR
FAR FIELD STRESS AND STRAIN CONCENTRATION FACTORS
NOTCH ROOT STRAIN (IN/IN)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
0.0025
0.005
0.0075
0.0100
0.0125
0.0150

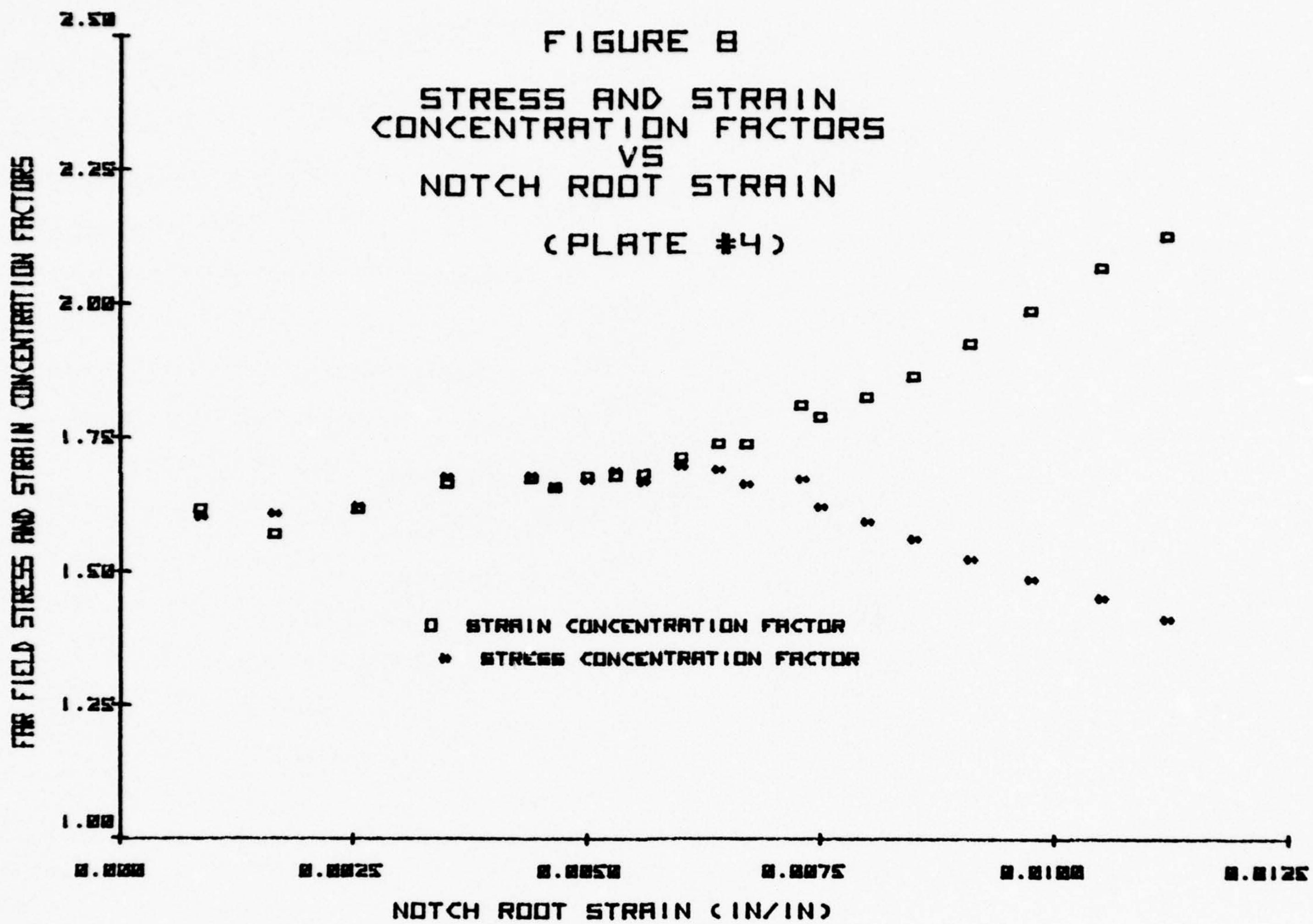


FIGURE 8
STRESS AND STRAIN
CONCENTRATION FACTORS
VS
NOTCH ROOT STRAIN
(PLATE #4)
FAR FIELD STRESS AND STRAIN CONCENTRATION FACTORS
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.000
0.0025
0.0050
0.0075
0.0100
0.0125
NOTCH ROOT STRAIN (IN/IN)
STRAIN CONCENTRATION FACTOR
STRESS CONCENTRATION FACTOR

is the net cross-sectional area of the plate taken at the notch.

Figures 9-12 show the deviation of the test data from Neuber's relation. The data plotted for plate number two in Figure 10 have a discontinuity in the region of 0.6 to 0.8 percent strain. This is attributed to poor data obtained from strain gage number two prior to its failure. It can be seen that once the notch root strains reach the region of plasticity, Neuber's relation is in error to a significant degree. It can also be seen that the error increases as the level of notch root strain increases.

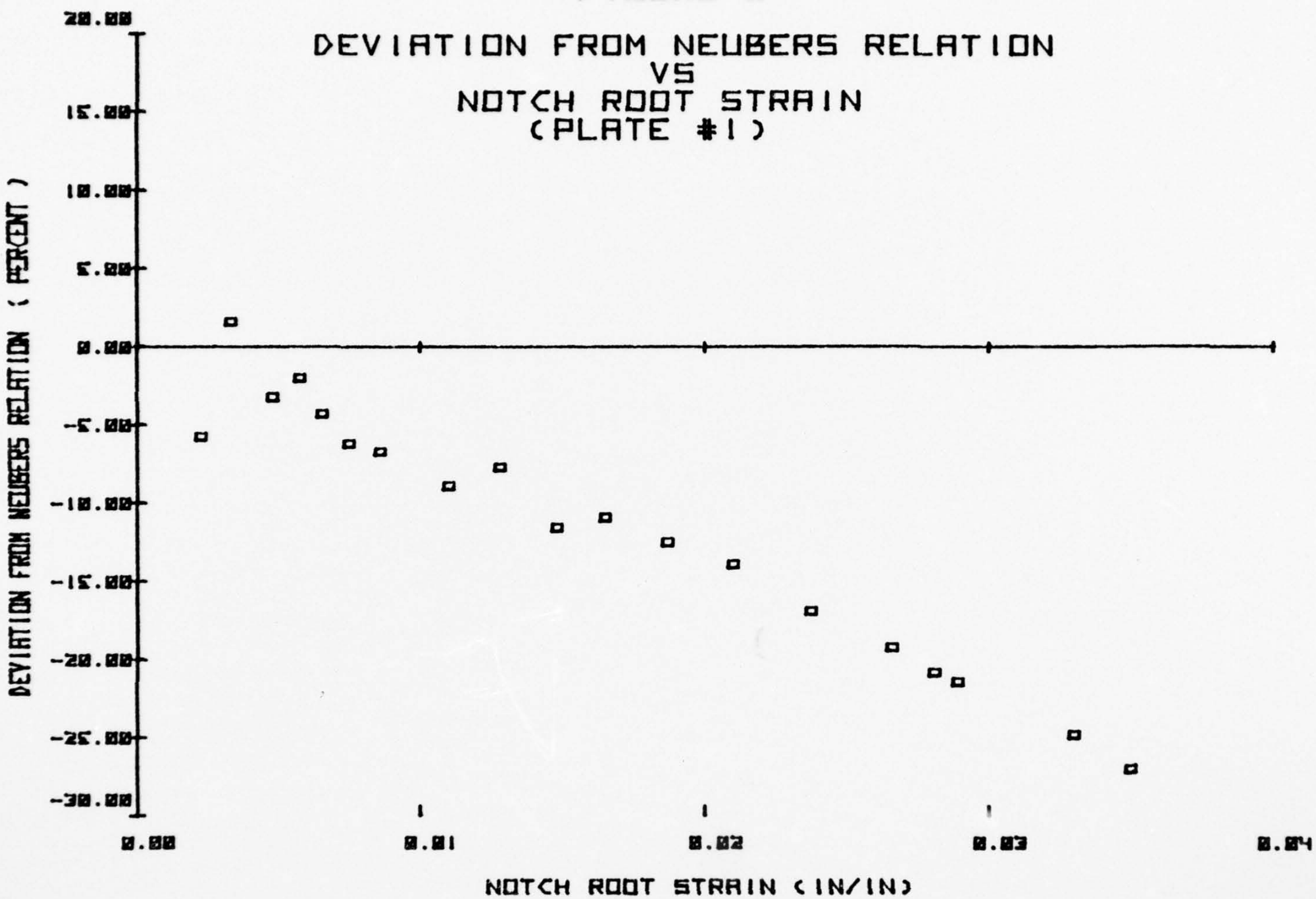


FIGURE 9

DEVIATION FROM NEUBERS RELATION
VS
NOTCH ROOT STRAIN
(PLATE #1)

FIGURE 10

DEVIATION FROM NEUBERS RELATION
VS
NOTCH ROOT STRAIN
(PLATE #2)

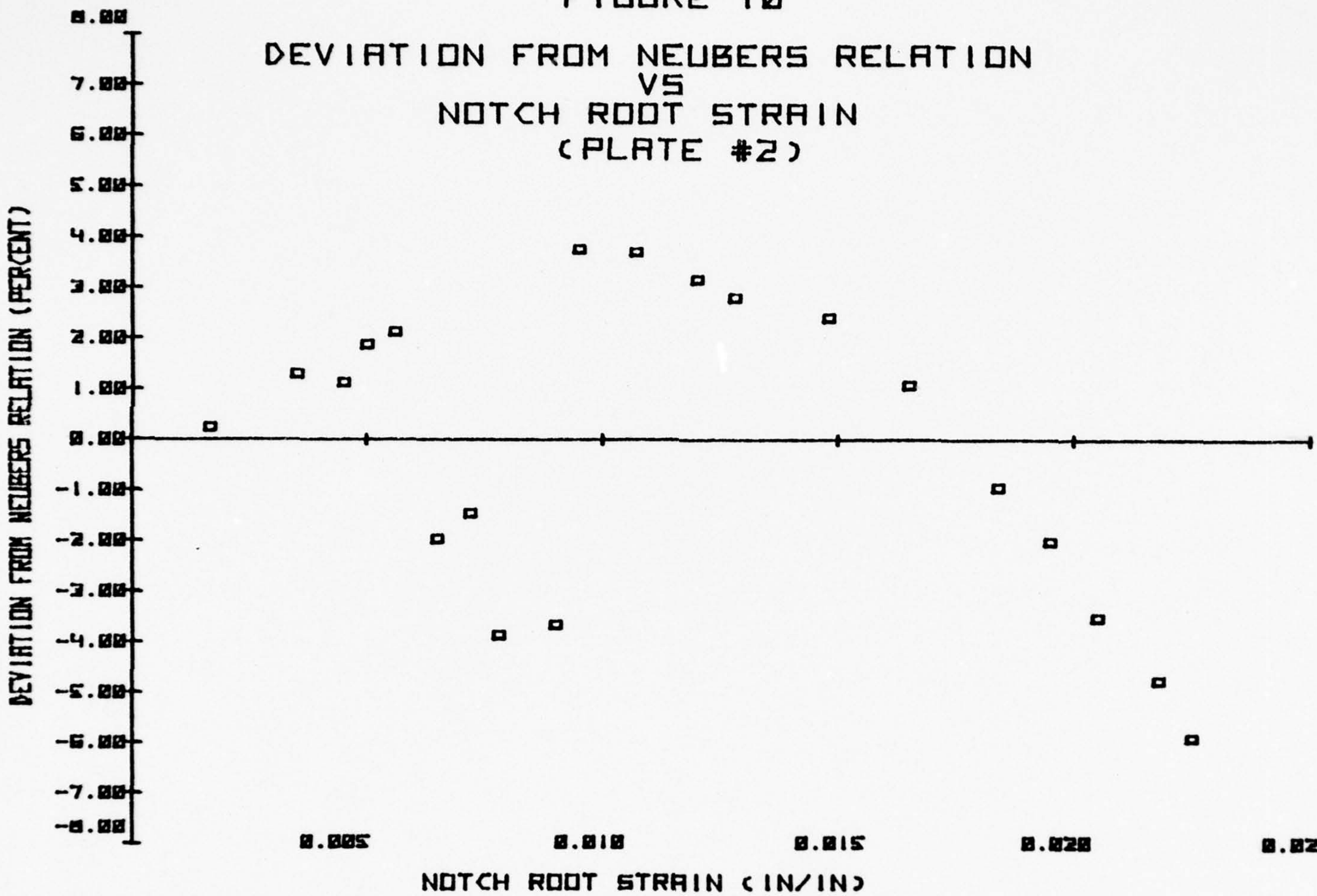


FIGURE 11

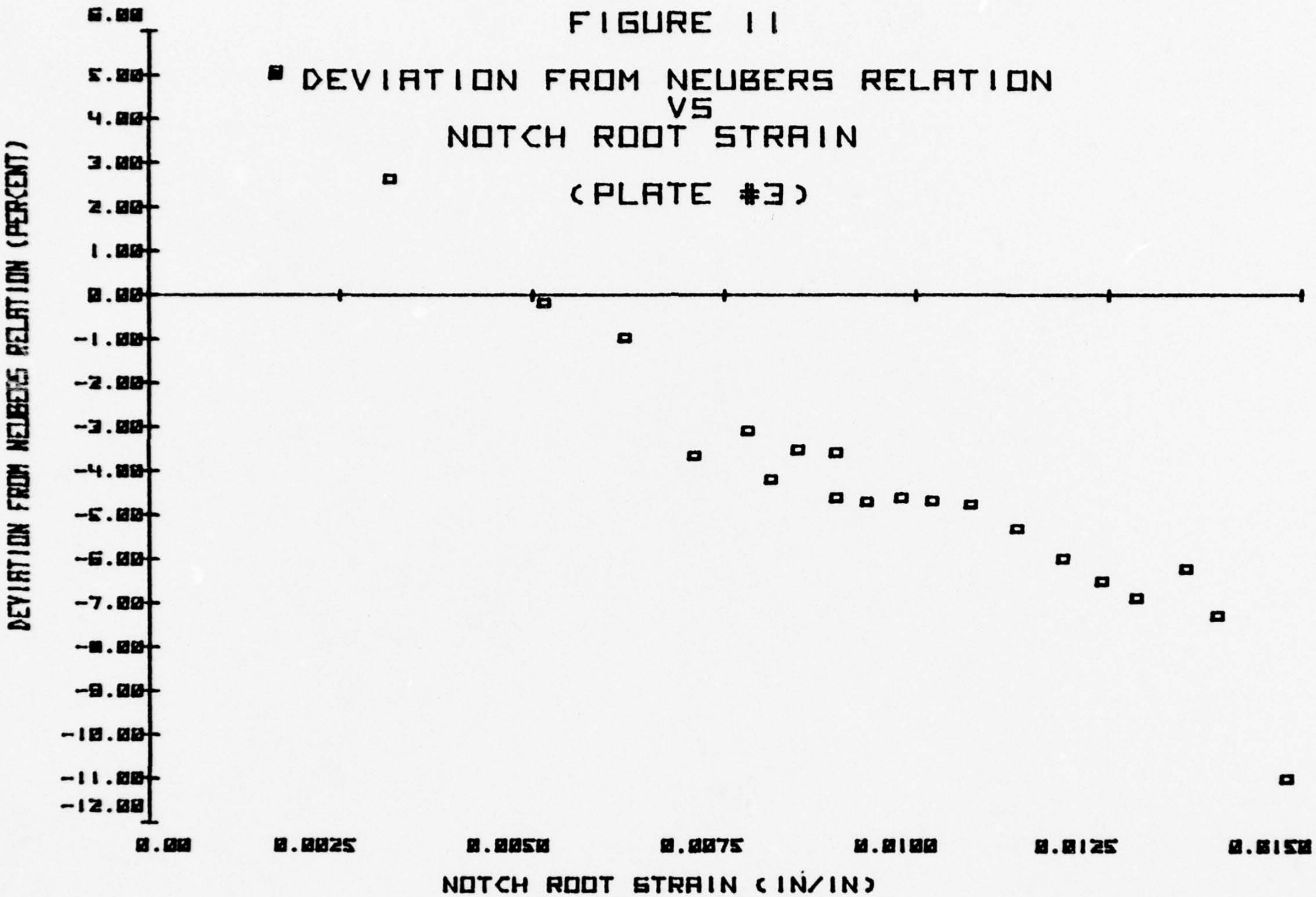
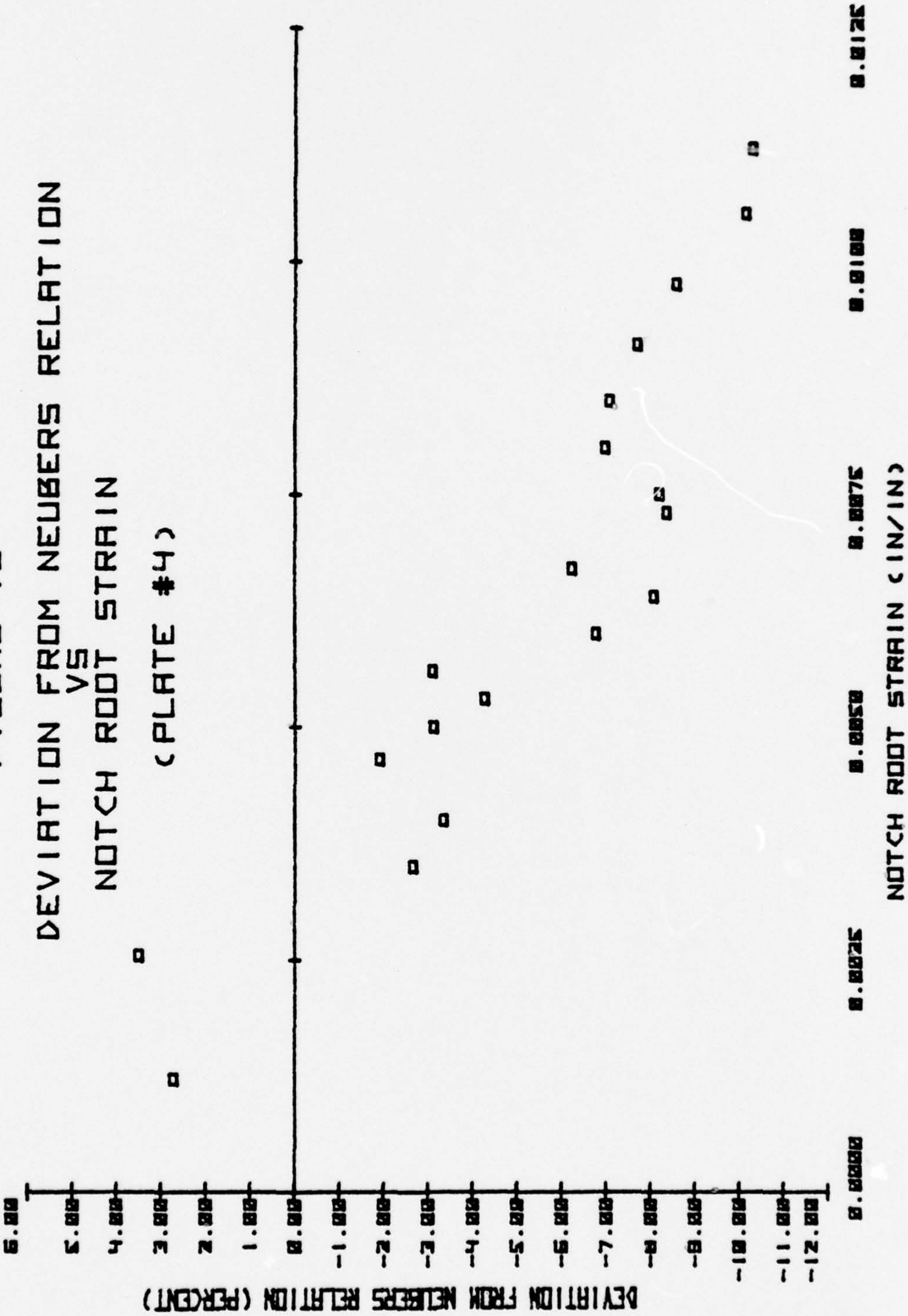

DEVIATION FROM NEUBERS RELATION
VS
NOTCH ROOT STRAIN
(PLATE #3)
DEVIATION FROM NEUBERS RELATION (PERCENT)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
-8.00
-9.00
-10.00
-11.00
-12.00
0.00
0.0025
0.0050
0.0075
0.0100
0.0125
0.0150
NOTCH ROOT STRAIN (IN/IN)

FIGURE 12
DEVIATION FROM NEUBERS RELATION
VS
NOTCH ROOT STRAIN
(PLATE #4)



III. FINITE ELEMENT ANALYSIS

A. INTRODUCTION

The finite element method has proven to be a powerful tool for analysis of complex problems in structural engineering. A dominant reason for its quick acceptance and extensive application in engineering practice is due to its complete generality.

For the reason of generality, this investigation examined the feasibility of forming an analytical method of observing local stress behavior in the area of stress concentrations for flat plates in plane stress. If the results of a finite element analysis compared favorably with actual test data, it could be postulated that models of other stress concentration factors and material properties would be equally valid.

1. Survey of Available Finite Element Analysis Programs

Finite element programs available at the Naval Postgraduate School were surveyed for the best available program to use in a nonlinear finite element analysis of flat plates in plane stress.

The scope of nonlinear programs available was quite narrow. Program EPLAS [Ref. 6] has been translated to FORTRAN IV and made operational. Programs NONSAP [Ref. 9] and ADINA [Ref. 10] were also operational and available. Program EPLAS used a scheme of constant strain triangles in an analysis of plates in plane stress. Because the intricacy of the small

triangles required to define the area of stress concentration did not lead to easily redefining the model, program EPLAS was not considered appropriate for this investigation. Program NONSAP contained a library of element models as well as material models, and it was considered appropriate for this investigation. However, the most flexible and convenient to use of the three programs surveyed was program ADINA (Automatic Dynamic Incremental Nonlinear Analysis).

Program ADINA is a general purpose linear and nonlinear static and dynamic finite element program. Structural matrices are stored in compacted form and element information is stored by blocks in low speed storage. The program is an out-of-core solver; i.e., the equilibrium equations are processed in blocks, and very large finite element systems can be considered. There is practically no high speed storage limit on the number of finite elements used.

For nonlinear response, an incremental solution of the equilibrium equations is used. The linear effective stiffness matrix, the linear stiffness matrix and the load vectors are assembled in low speed storage. During a step-by-step solution, the linear effective stiffness matrix is updated for the nonlinearities in the system. The incremental solution scheme corresponds to a modified Newton iteration. To control accuracy, the number of steps between equilibrium iterations and between reforming a new effective stiffness matrix can be controlled by the user.

2. The Finite Element Method

The finite element method of stress analysis is well known and widely used; therefore, only the basic aspects of isoparametric elements in plane stress need review.

A coordinate transform from the η, ξ plane to the x,y plane as shown in Figure 13 allows the element to be represented as an arbitrary shape in the x,y plane. Applying the concepts of minimum potential energy, a stiffness matrix is determined by integrating numerically over the η, ξ plane using gauss quadrature. Therefore, stresses are calculated at each gauss quadrature point in the element. Figure 14 shows a typical isoparametric element and gauss quadrature points for a four point gauss quadrature.

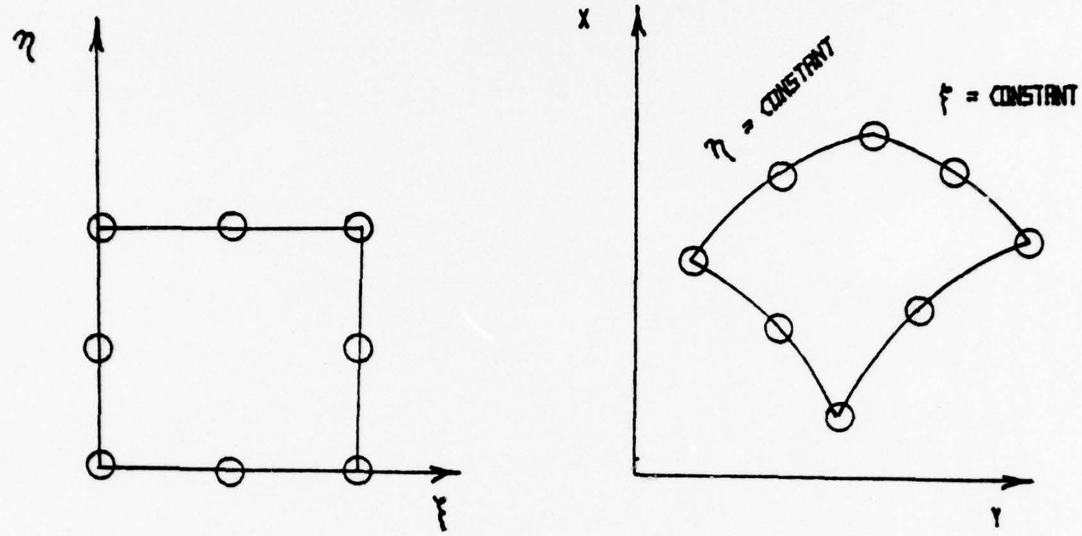
B. FINITE ELEMENT METHODS USED

1. Element Models

Since it was necessary to generate a variety of models for flat plates in plane stress, two FORTRAN IV computer programs, POINTS and NPOINTS, were created to generate the appropriate element data for program ADINA.

Program POINTS created a grid that modeled one quadrant of the entire test plate. This model contained 507 nodes and 228 finite elements; the model generated by this program for plate number one is shown in Figure 15. Through a minor modification to the program, a smaller model consisting of 351 nodes and 156 elements was generated. The mesh generated in this manner for plate number one is shown

FIGURE 13



GAUSS QUADRATURE POINTS
(4 POINT GAUSS QUADRATURE)

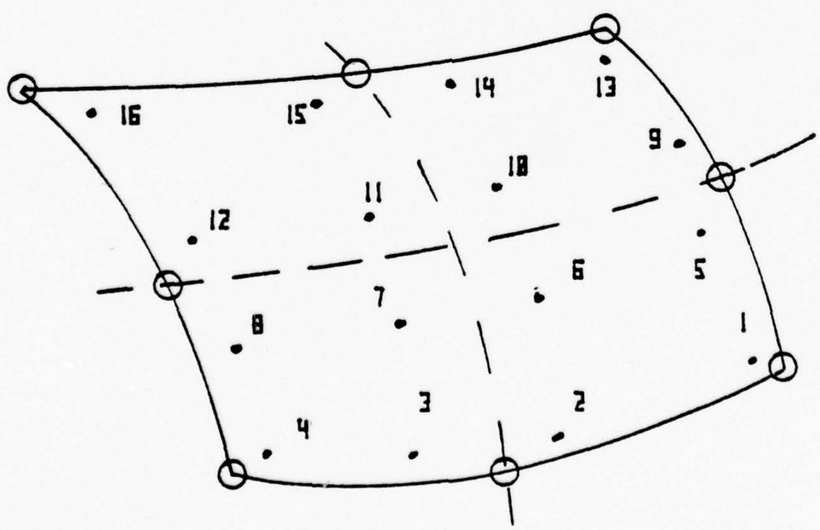


FIGURE 14

FINITE ELEMENT MODEL GENERATED
BY PROGRAM POINTS

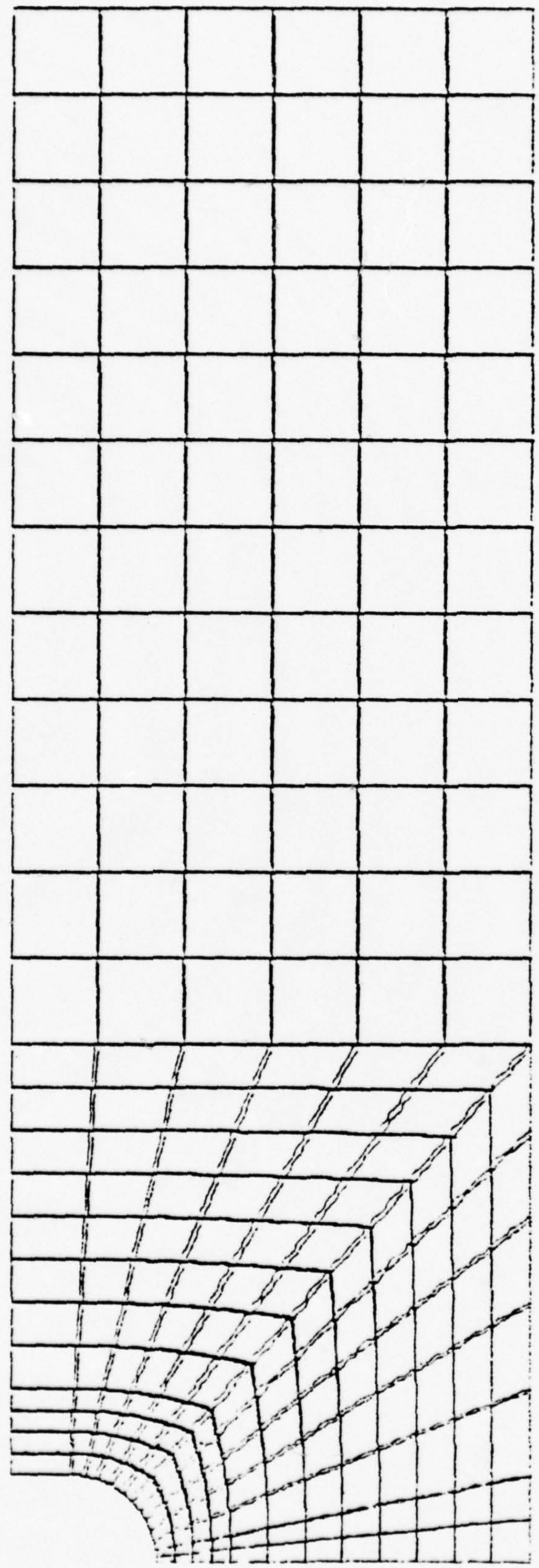


FIGURE 15

in Figure 16. In view of the theories of St Venant, the smaller model was considered adequate for use in this analysis.

Program NPOINTS was a smaller version of program POINTS. It created a grid that was the same size as the smaller model generated by POINTS. Although equal in physical size, the model generated by NPOINTS contained 189 nodes and 78 elements. A model generated by NPOINTS for plate number 1 is shown in Figure 17.

Both mesh generation programs were general in nature. By simply redefining the vector of variables which described the notch at the edge of the plate, a new mesh could be generated. Both mesh schemes were tested for accuracy and efficiency in program ADINA.

For the plate model tested, the two elastic stress concentration factors calculated using the two mesh schemes were essentially equal. The mesh generated by POINTS required 26.5 minutes of computer time for 20 load applications, while the mesh generated by NPOINTS required 23 minutes of computer time for 20 load applications. On the basis of relative efficiency, the mesh generated by NPOINTS was selected as the model to use for the finite element analysis portion of this investigation. Models generated by NPOINTS for notched specimens 2, 3, and 4 are shown in Figures 18-20 respectively. All plates were modeled so that Gauss quadrature point number 3 in element number 1 coincided with the center of the strain gage on the actual test specimen.

FINITE ELEMENT MODEL GENERATED

BY PROGRAM POINTS

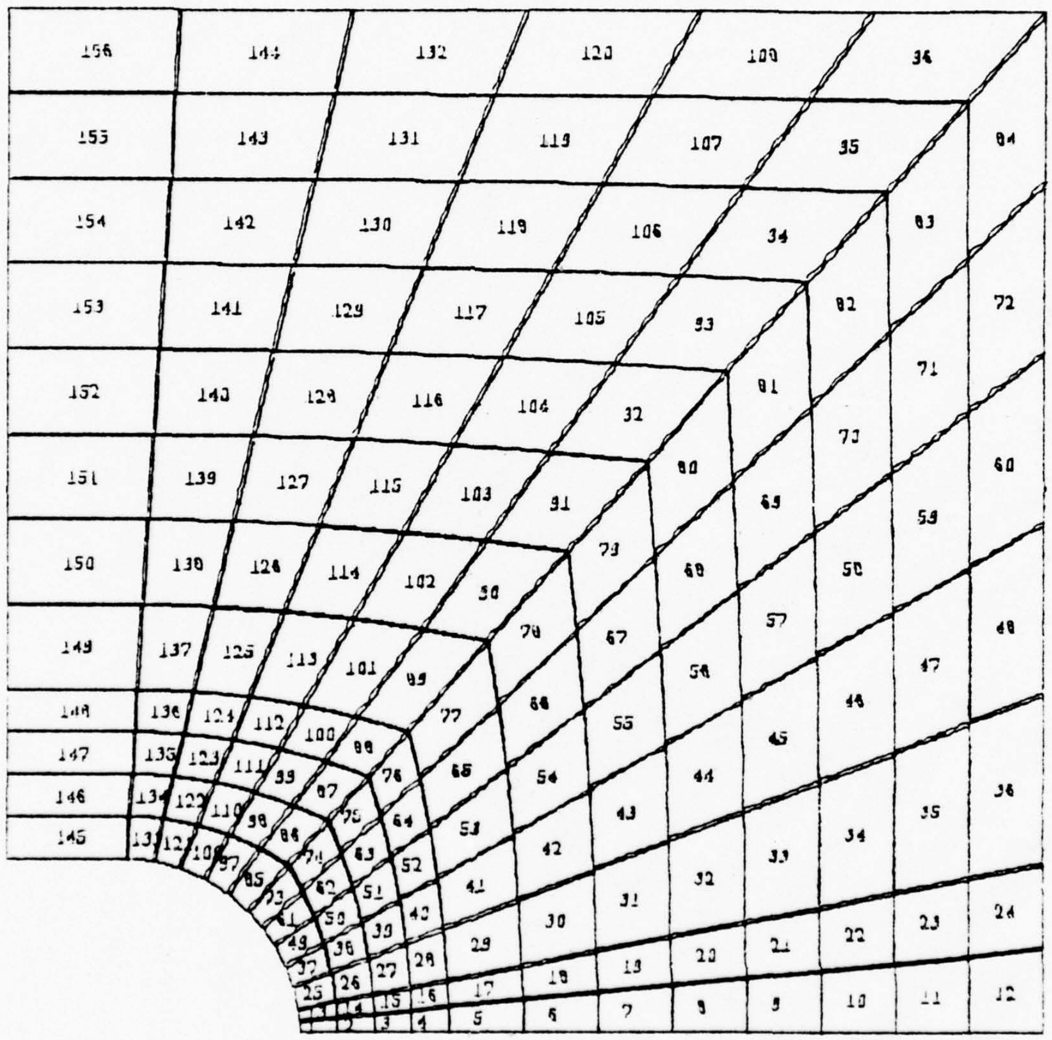


FIGURE 16

FINITE ELEMENT MODEL FOR PLATE #1

GENERATED BY PROGRAM NPOINTS

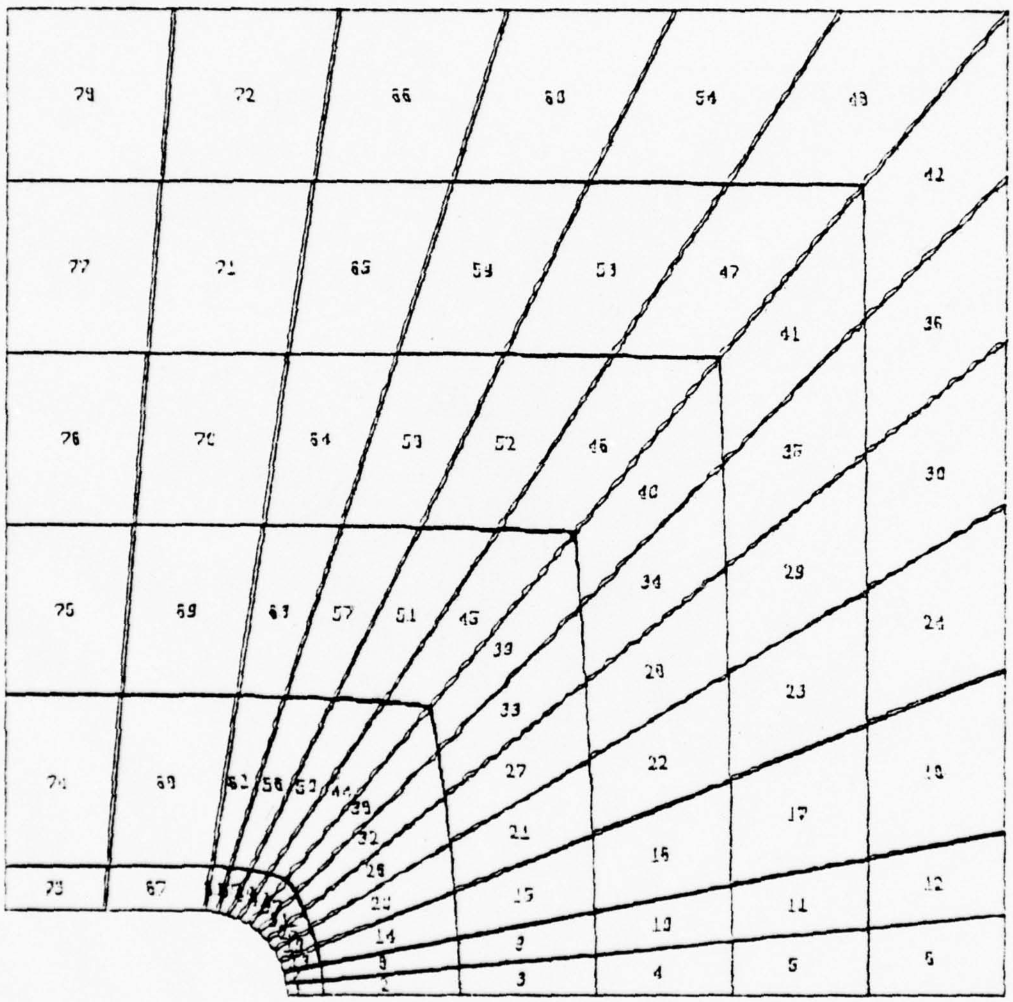


FIGURE 17

FINITE ELEMENT MODEL FOR PLATE #2

GENERATED BY PROGRAM NPOINTS

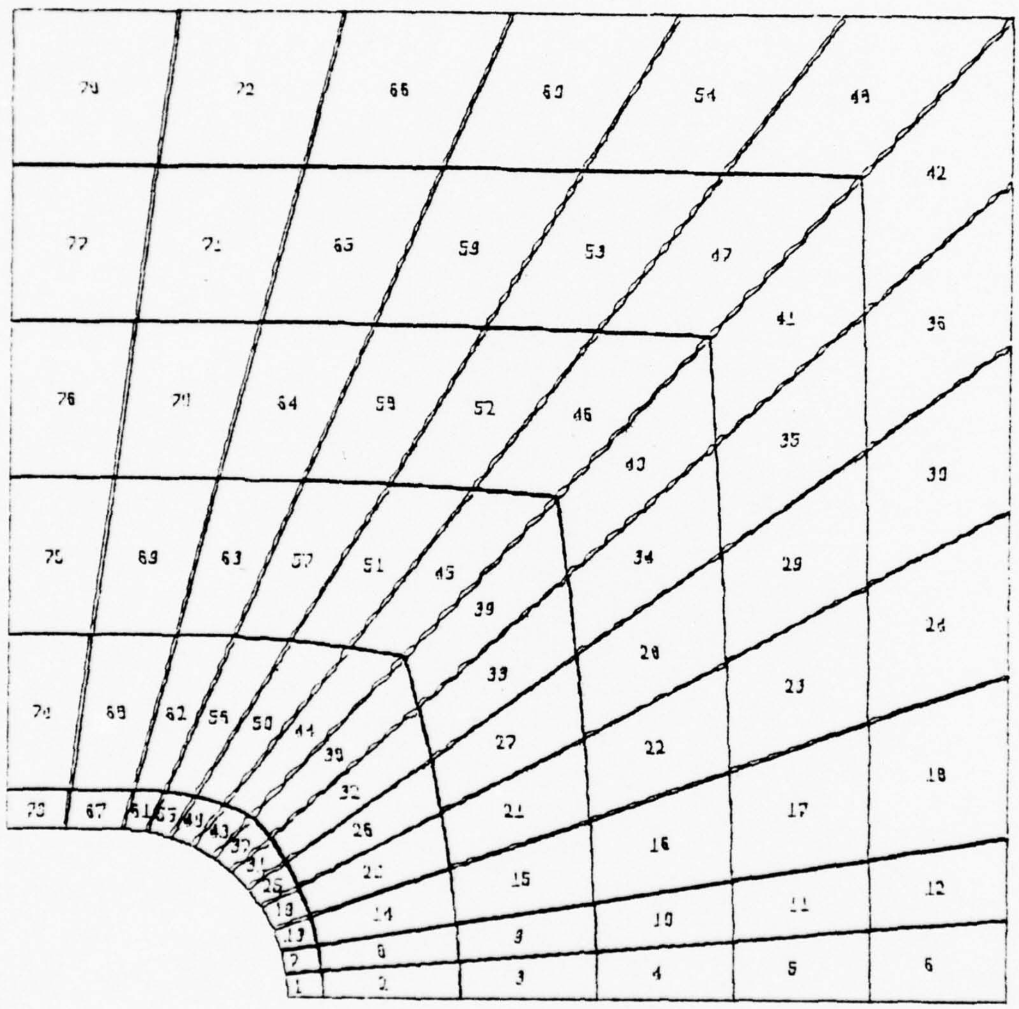


FIGURE 18

FINITE ELEMENT MODEL FOR PLATE #3

GENERATED BY PROGRAM NPOINTS

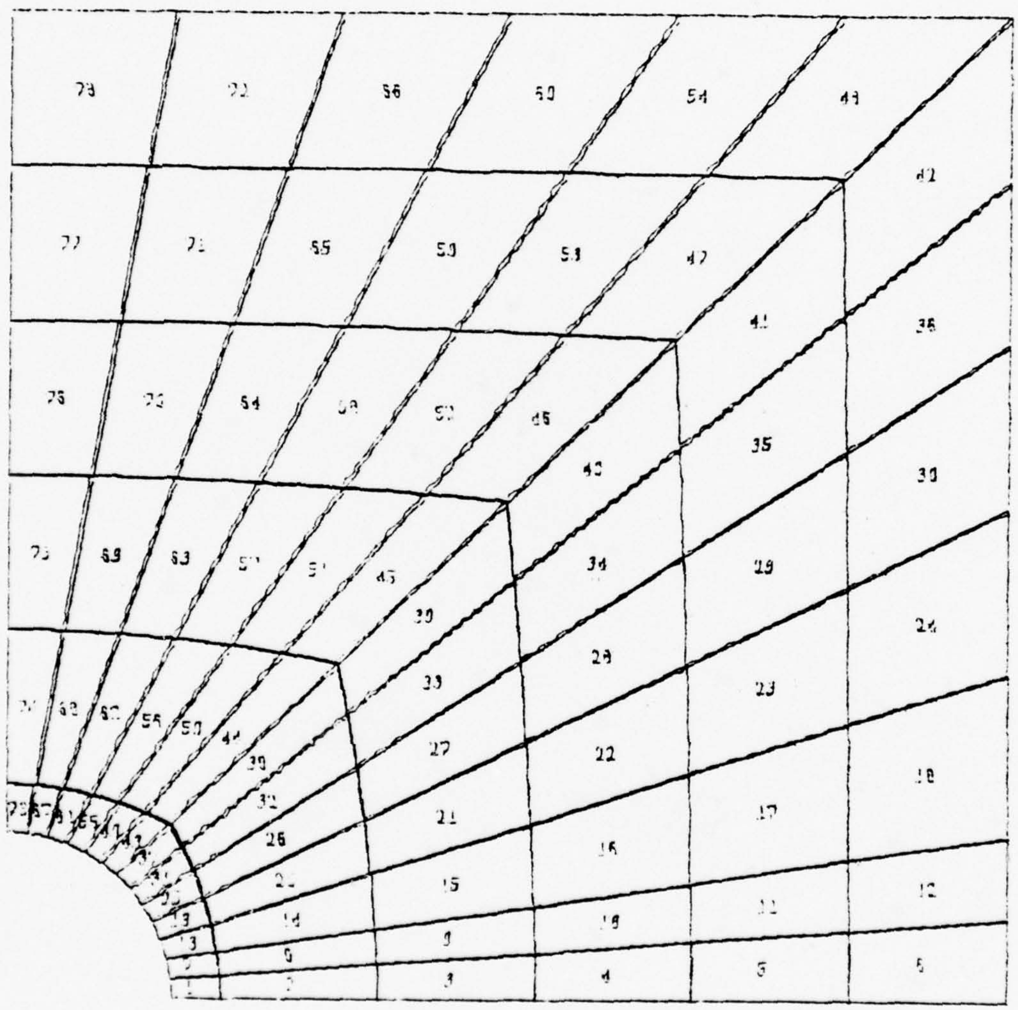


FIGURE 19

FINITE ELEMENT MODEL FOR PLATE #4

GENERATED BY PROGRAM NPOINTS

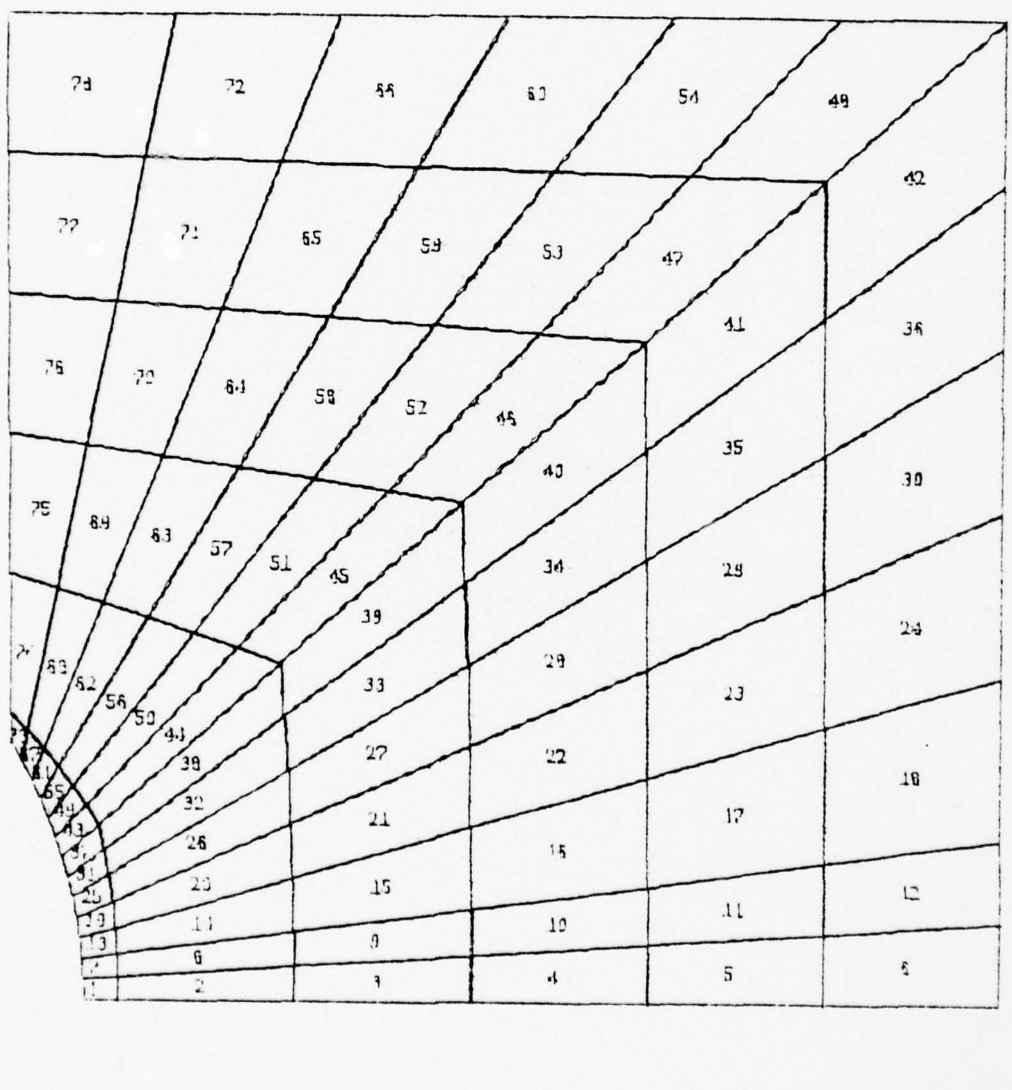


FIGURE 20

2. Symmetry and Load Considerations

Meshes generated by program NPOINTS, as shown in the above mentioned figures, model only one quarter of the plate. The plates are symmetrical and two planes of symmetry cut through the plates. Therefore, as shown in Figure 21, by imposing the boundary conditions of zero displacement in the y-direction for boundary 1, and zero displacement in the z-direction for boundary 2, it is necessary to model only one quarter of the plate for a complete analysis.

Loads can be applied to the model only at nodal points; Figure 21 shows the formulation of the applied loads. A uniform stress is assumed across the boundary where the loads are applied. A load that would produce one half the stress in the element is applied at one node and an equal load is applied to the opposite node. If two elements share a common node, the loads are summed at that node.

3. Material Model

Program ADINA provided for the use of a bilinear stress-strain relationship when defining the material properties of the two-dimensional continuum elements. The material model used was the elastic-plastic (von Mises isotropic hardening) model. This model is defined by Young's modulus, Poisson's ratio, yield stress in simple tension and a strain hardening modulus. To model the actual properties of the test material, the modulus of elasticity as determined in the uniaxial tensile stress-strain test was used as Young's modulus and 0.3, a standard for aluminum, was used as Poisson's ratio. A linear least squares fit of the uniaxial

BOUNDRY CONDITIONS AND LOADS
ON A FINITE ELEMENT MODEL

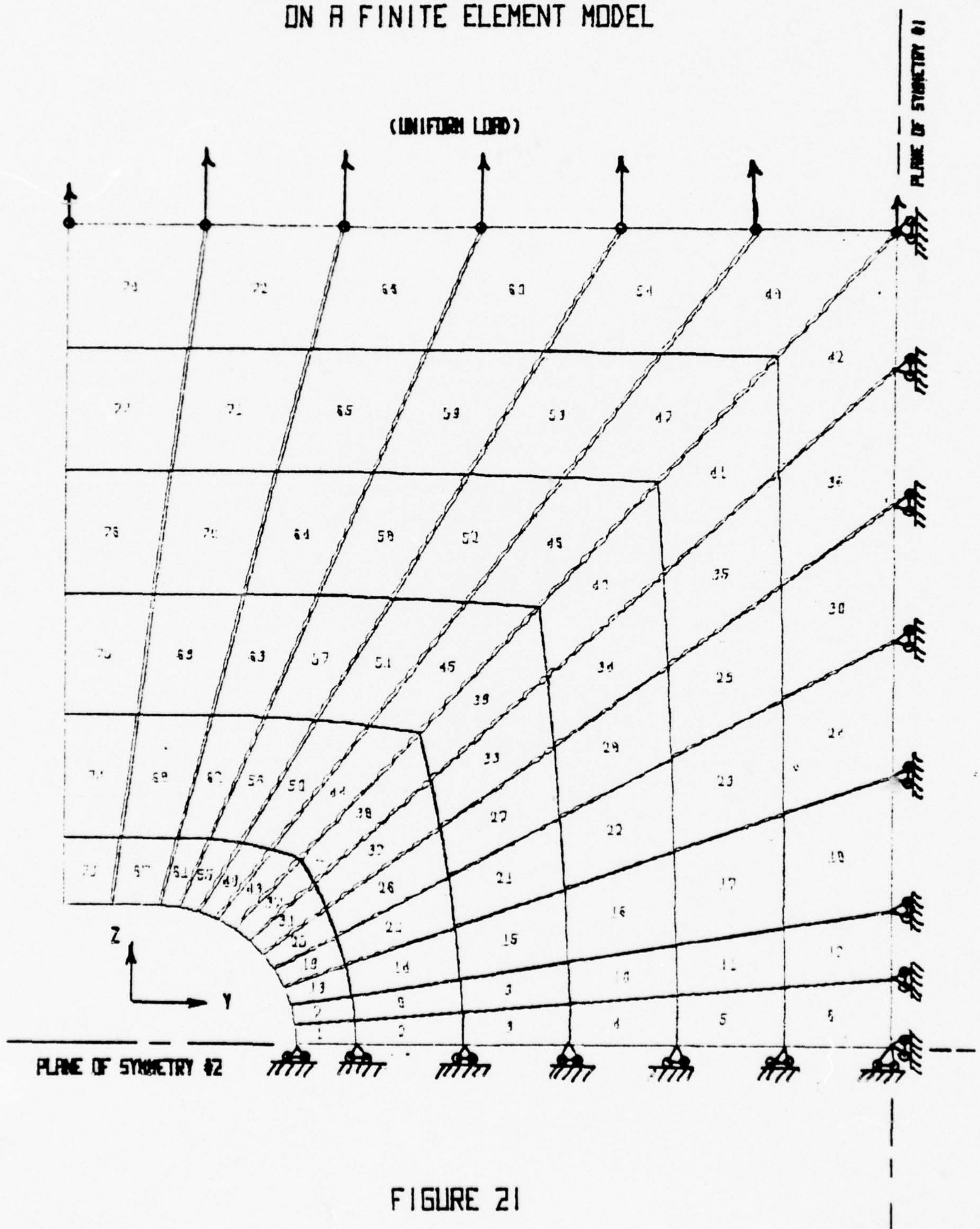


FIGURE 21

tensile stress-strain data between 1.0 percent and 2.1 percent strain was used to calculate a hardening modulus of 399.606 ksi. The intersection of the modulus of elasticity and the line defining the hardening modulus was taken to be the yield stress of 77.173 ksi for the model. Figure 22 shows the bilinear stress-strain assumption compared with the uniaxial tensile test data.

4. Analysis Procedures

A four point Gauss quadrature, which is the allowable maximum, was specified in the program input parameters to obtain results as close to the notch root boundary as possible. Because of this requirement, out of core storage requests in the standard ADINA JCL cards of reference 10 had to be modified to accommodate the size of the system being analyzed. The loads applied to the nodes shown in Figure 21 were applied in thirty increments. The first four loads were scaled to create a stress at the notch root equal to the yield stress. The remaining twenty-six increments were evenly spaced between load number four and the highest load recorded during the corresponding notched flat plate specimen test.

C. RESULTS OF FINITE ELEMENT ANALYSIS

Tabular results of the finite element analysis using program ADINA are in Appendix B. The comparison of far field stress concentration factors from the finite element analysis and the notched test specimens were as follows:

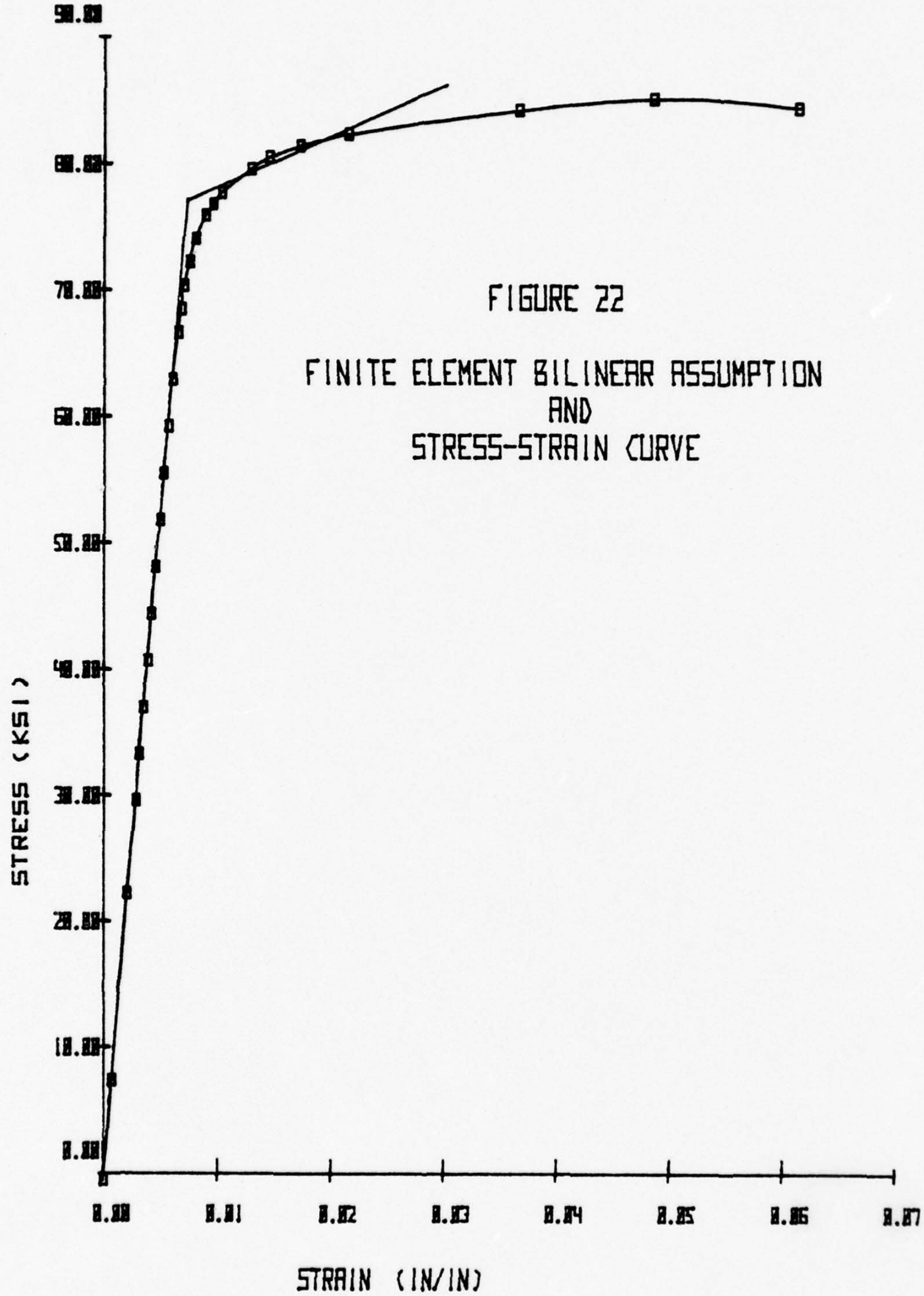


FIGURE 22

FINITE ELEMENT BILINEAR ASSUMPTION
AND
STRESS-STRAIN CURVE

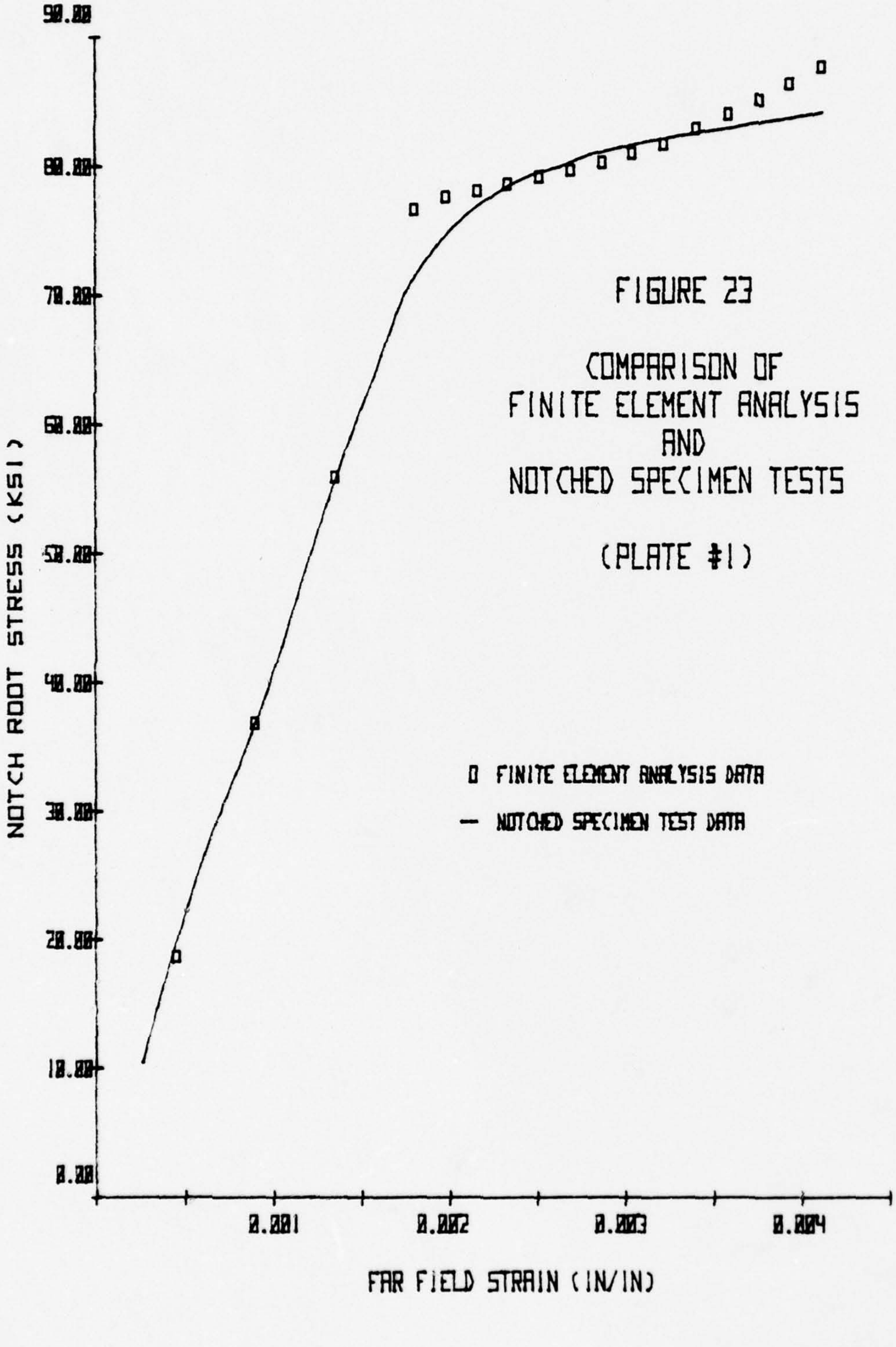
Far Field Elastic

Stress Concentration Factors

Plate	Finite Element	Specimen Test	Variance
1	3.92	3.60	8.9%
2	3.33	3.23	3.2%
3	2.51	2.45	2.4%
4	1.63	1.65	1.2%

The results of the finite element analysis compared favorably with the results obtained from the notched specimen tests for plates 2, 3 and 4. In addition, if the far field elastic stress concentration factor for notched specimen number one was calculated using gage number 2 only, the variance would be 3.4 percent, comparable to the other plates modeled.

Figures 23-26 compare notch root stress versus far field strain for the tensile test specimens and the finite element model. The correlation between finite element analysis and tensile test specimen data also compares favorably in Figures 23-26. The trend of the notch root stress to increase more rapidly after reaching the 80 ksi range is attributed to Gauss quadrature points in element number two becoming plastic and dramatically changing its ability to carry a load. The effect is especially noticeable because of the difference in size of the elements.


90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
NOTCH ROOT STRESS (KSI)
0.001
0.002
0.003
0.004
FAR FIELD STRAIN (IN/IN)
FIGURE 23
COMPARISON OF
FINITE ELEMENT ANALYSIS
AND
NOTCHED SPECIMEN TESTS
(PLATE #1)
FINITE ELEMENT ANALYSIS DATA
NOTCHED SPECIMEN TEST DATA

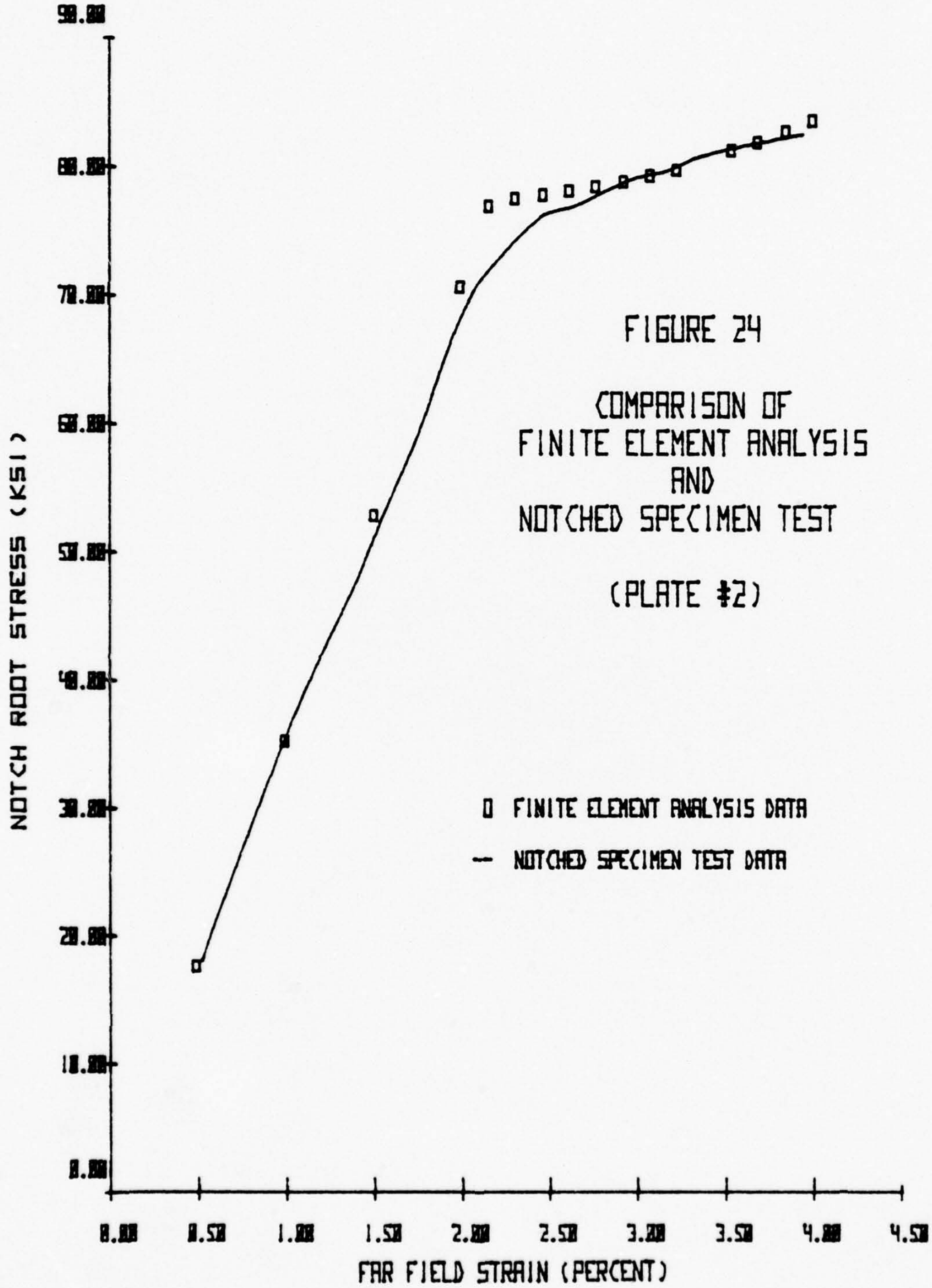


FIGURE 24
COMPARISON OF
FINITE ELEMENT ANALYSIS
AND
NOTCHED SPECIMEN TEST
(PLATE #2)
FINITE ELEMENT ANALYSIS DATA
NOTCHED SPECIMEN TEST DATA
NOTCH ROOT STRESS (KSI)
FAR FIELD STRAIN (PERCENT)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00

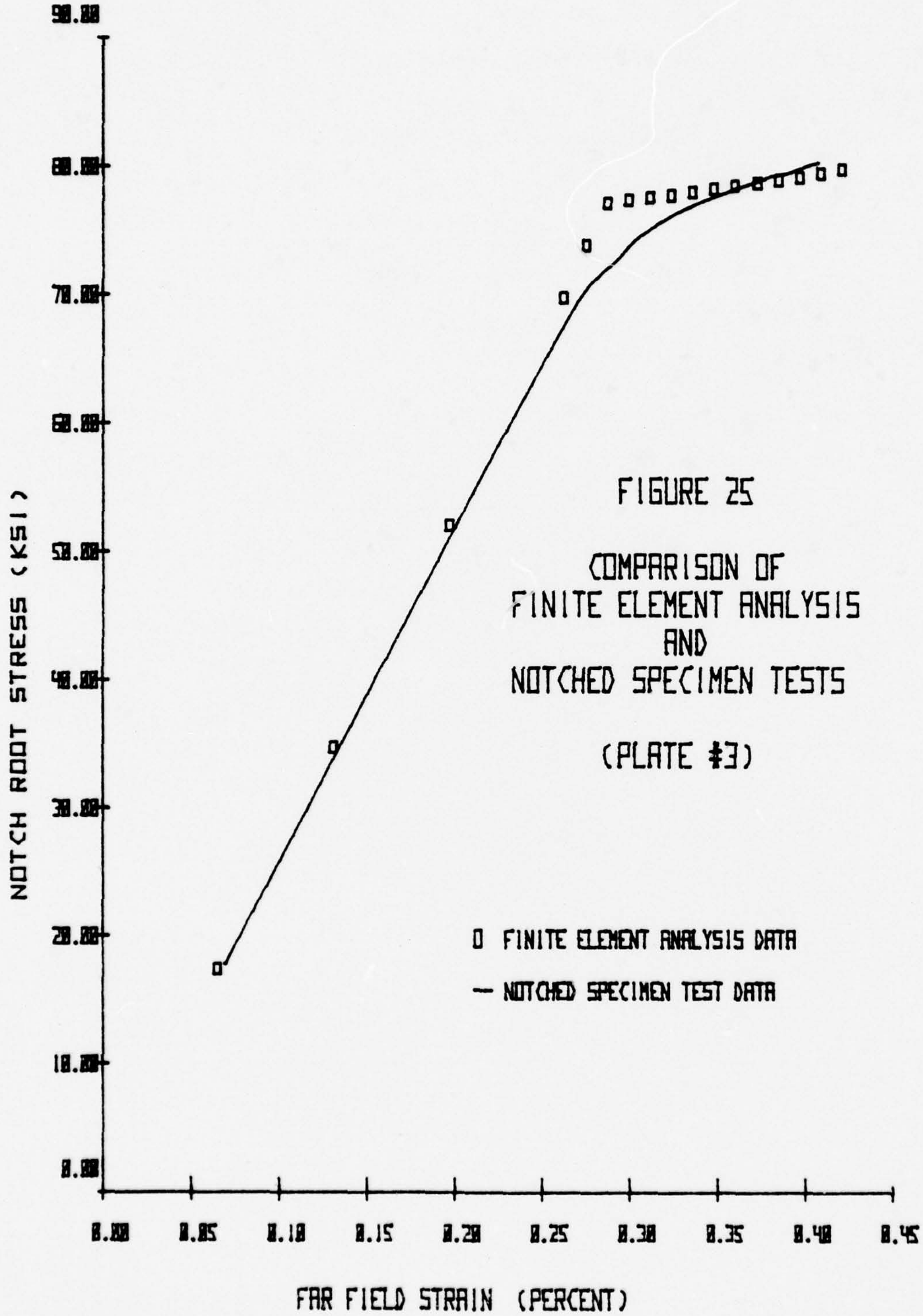


FIGURE 25
COMPARISON OF
FINITE ELEMENT ANALYSIS
AND
NOTCHED SPECIMEN TESTS
(PLATE #3)
□ FINITE ELEMENT ANALYSIS DATA
— NOTCHED SPECIMEN TEST DATA
NOTCH ROOT STRESS (KSI)
FAR FIELD STRAIN (PERCENT)
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45

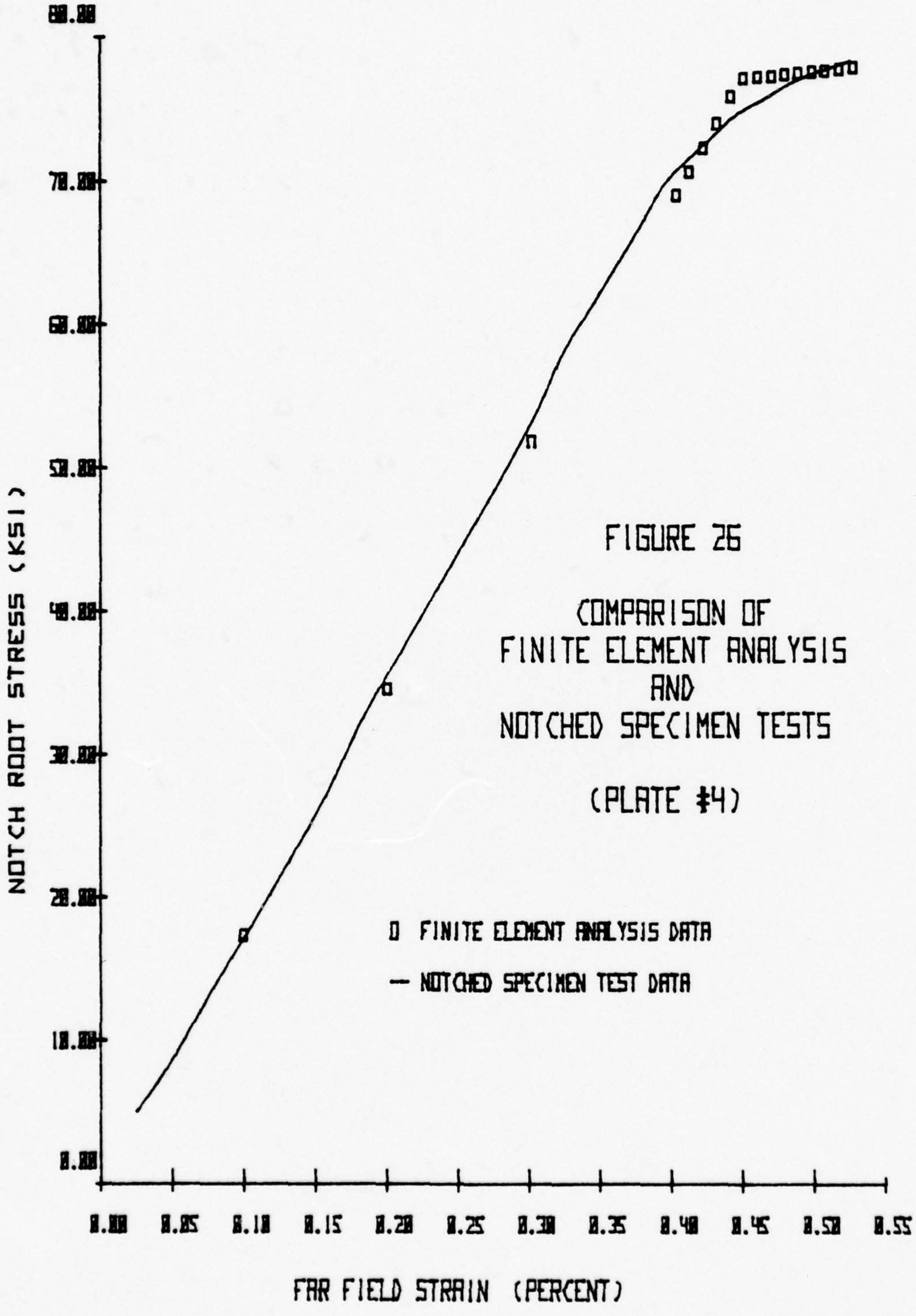


FIGURE 26

COMPARISON OF
FINITE ELEMENT ANALYSIS
AND
NOTCHED SPECIMEN TESTS

(PLATE #4)

IV. INVESTIGATION OF METHODS TO RELATE FAR FIELD STRAIN TO NOTCH ROOT STRESS

A. A HEURISTIC ANALYSIS

A heuristic analysis of far field strain and notch root stress was pursued after observing in Figures 23-26 that the plot of notch root stress versus far field strain maintained the same shape, although in a compressed form, as the original stress-strain relationship obtained in the uniaxial tensile stress-strain tests. Therefore, a local stress far field strain relationship was developed by dividing the local strains by the far field stress concentration factor, for a given stress.

For each notched test specimen, the new stress-strain relationship was developed and the far field strains from each test were used to verify the relationship by calculating stresses using the new stress-strain relation. The results are found in Tables 5, 12, 18, and 24 of Appendix A.

As can be seen from the tabular data, the stresses computed in this manner vary up to 4 percent from the stresses actually recorded during the testing of the notched specimen. It can also be observed that the error increases as the notch root strain increases.

B. A FAR FIELD STRESS AND STRAIN CONCENTRATION FACTOR POWER RELATION CURVE FIT

Another attempt to relate the far field strain and notch root stress involved finding a relation between the far field

stress and strain concentration factors. The method used to relate the two concentration factors was a power curve fit. In equation form it was assumed that

$$K_{\sigma} = (a)\ (K_{\varepsilon})^{b}$$

or

$$(\sigma/S) = (a)\ (\varepsilon/e)^{b}$$

Assuming that for every stress, there exists an influence coefficient, E', such that stress is the product of E' and strain, the above equation can be written

$$\sigma = Sa(\sigma/E'e)^{b}$$

solving for the notch root stress,

$$\sigma = e(Ea/(E')^{b})^{\frac{1}{1-b}}$$

Since this relation must also hold in the elastic limit (E'=E), the coefficient, a, must be given by

$$a = (\sigma/Ee)^{1-b} = (K_{t}(ff))^{1-b}$$

Therefore, substituting into the above,

$$\sigma = e(K_{t}(ff))\ (E/(E')^{b})^{\frac{1}{1-b}}$$

Two unknowns still remain in the above equation, the notch root stress and the influence coefficient, E'. Therefore, an iteration scheme using the relationship between stress and E' is necessary to calculate the notch root stress using this method.

To evaluate the relation of stress and E', the stresses of the stress-strain relationship (Figure 2 and Table 1) were divided by their corresponding strains to calculate an E' for that stress. The results are found in Table 6 of Appendix A and a plot of E' versus stress is found in Figure 27. A power curve fit method was used to calculate the power factor, b, from the data of far field stress and strain concentration factors.

Subroutine SOLVE of a data reduction program calculated the notch root stresses given an input of the far field strains. Figure 28 is a flowchart describing how subroutine SOLVE functioned.

The tabular results of the notch root stresses calculated by SOLVE are presented in Tables 7, 13, 19, and 25. Table 26 provides the data calculated to be the curve fit exponent. The tabular results show differences of up to fifteen percent between calculated stresses and actual stresses found in the notched specimen tests. It should be noted, however, that only one refinement was made in iterating to find the E' that related to the calculated stress.

C. RELATING THE INVERSE OF THE FAR FIELD STRESS AND STRAIN CONCENTRATION FACTORS IN A LEAST SQUARES LINEAR CURVE FIT

A third method of relating the far field strain to the notch root stress was to use the observation that the inverse of the far field strain concentration factor plotted against the inverse of the far field stress concentration factor was essentially linear. Figures 29-32 describe this relation

INFLUENCE COEFFICIENT VS STRESS

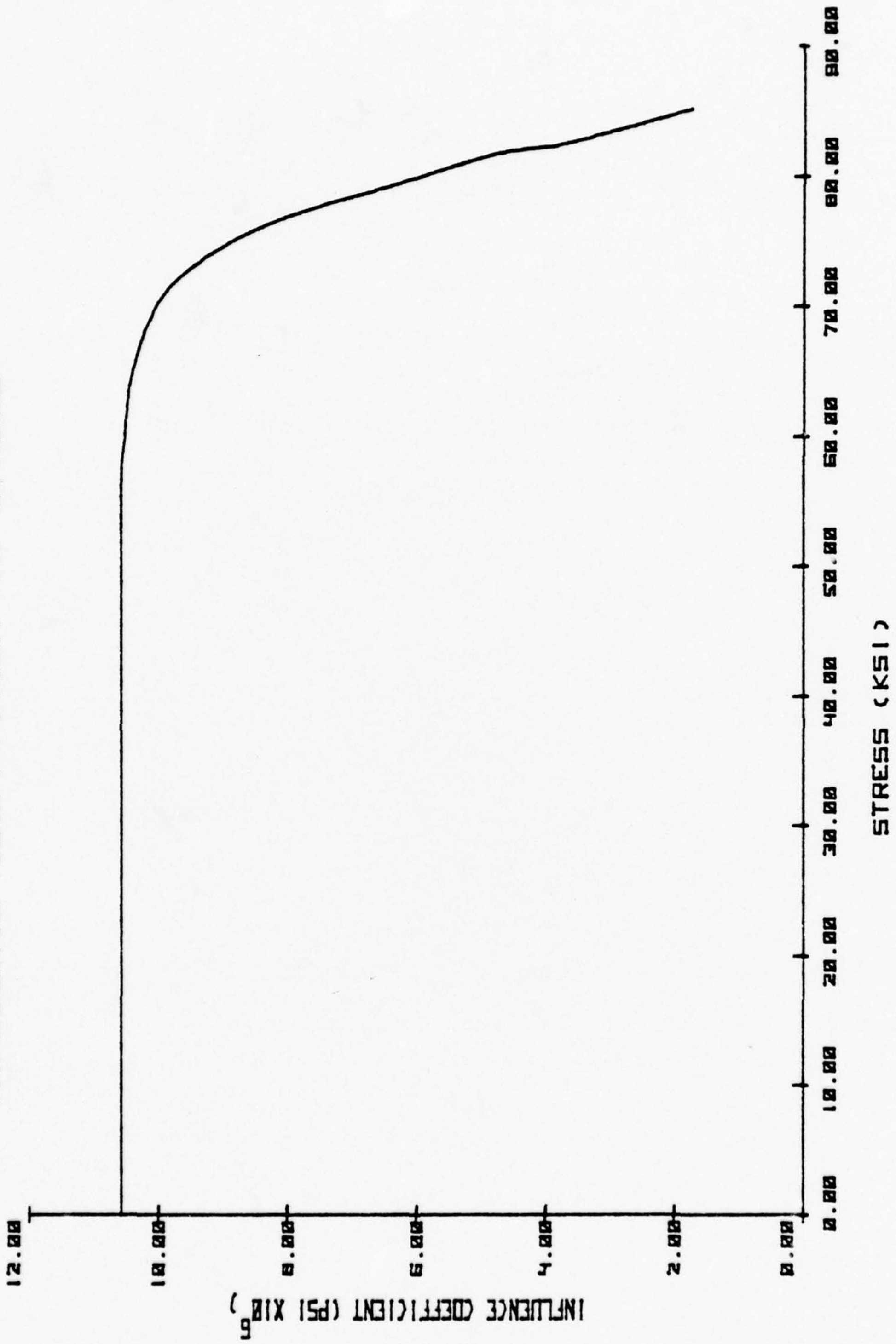


FIGURE 27

ALGORITHM FOR SUBROUTINES SOLVE & SOLVE2

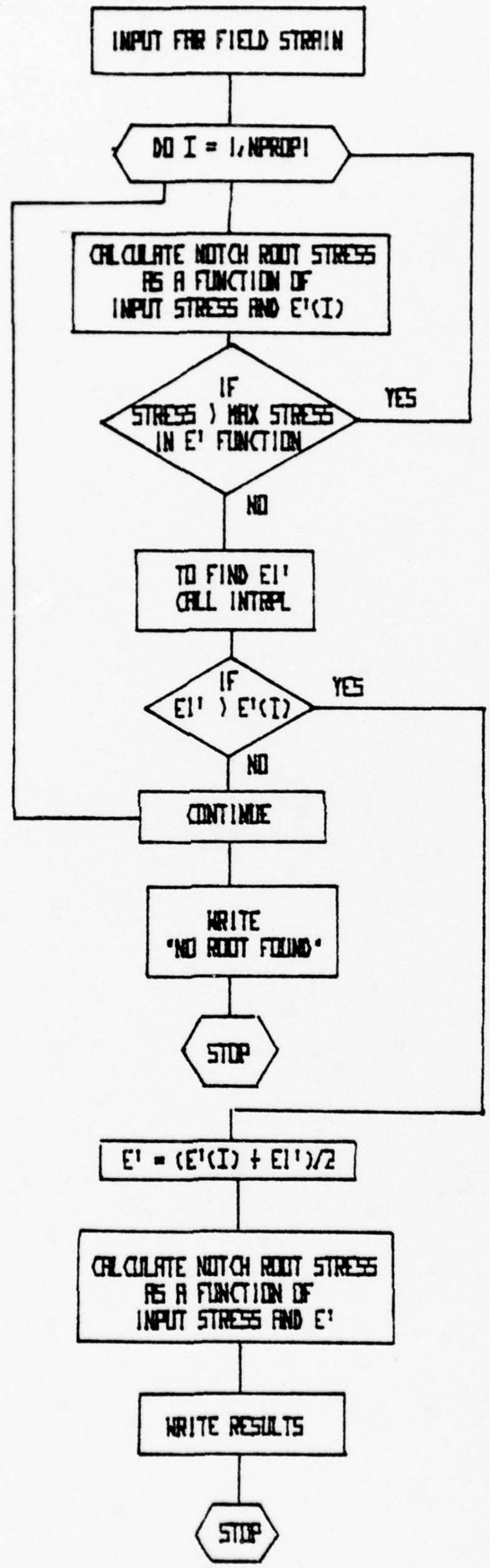


FIGURE 28

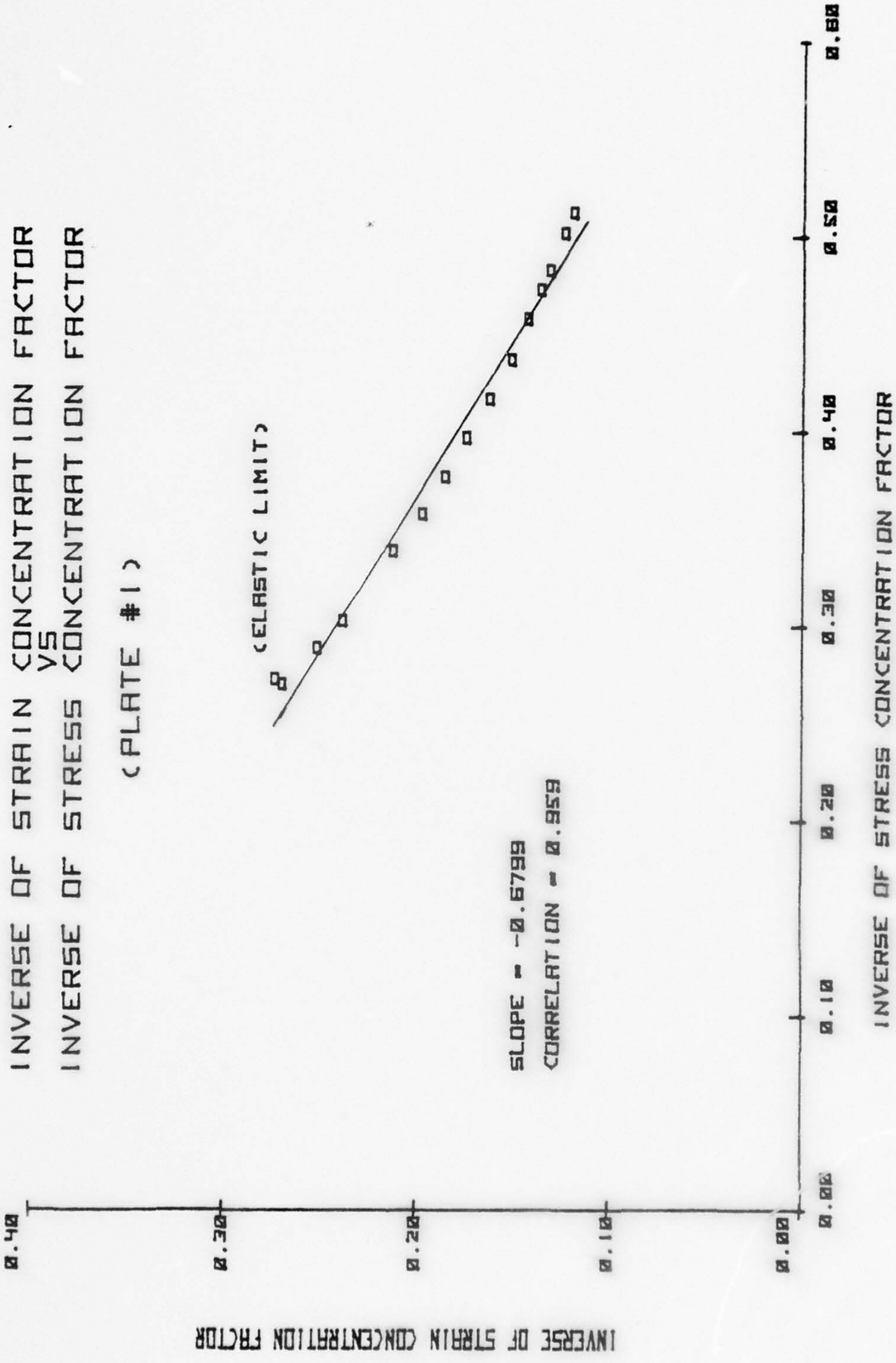

INVERSE OF STRAIN CONCENTRATION FACTOR
VS
INVERSE OF STRESS CONCENTRATION FACTOR
(PLATE #1)
(ELASTIC LIMIT)
SLOPE = -0.6799
CORRELATION = 0.959
INVERSE OF STRESS CONCENTRATION FACTOR
INVERSE OF STRAIN CONCENTRATION FACTOR
0.00
0.10
0.20
0.30
0.40
0.50
0.60

FIGURE 29

INVERSE OF STRAIN CONCENTRATION FACTOR
VS
INVERSE OF STRESS CONCENTRATION FACTOR

(PLATE #2)

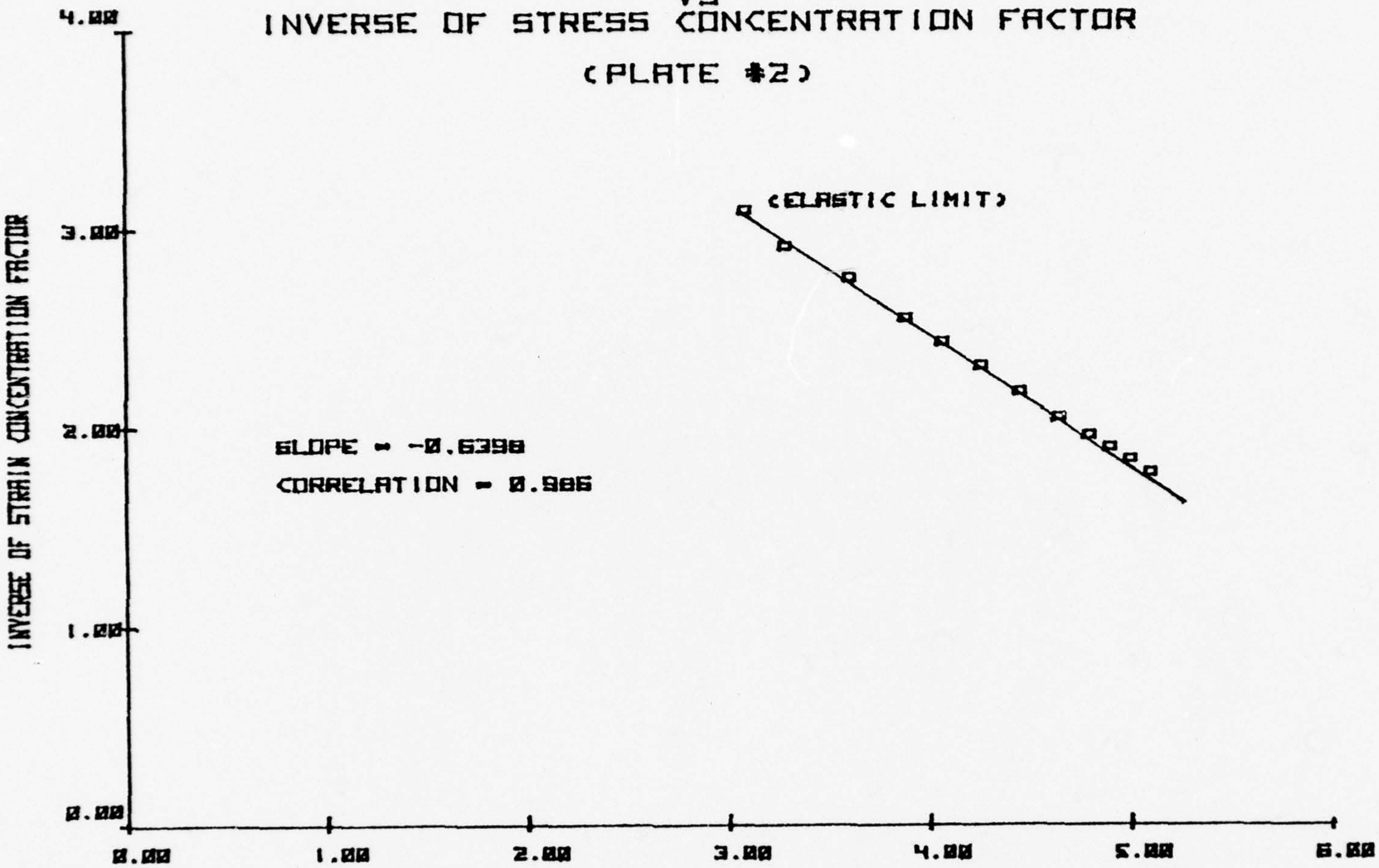


FIGURE 30

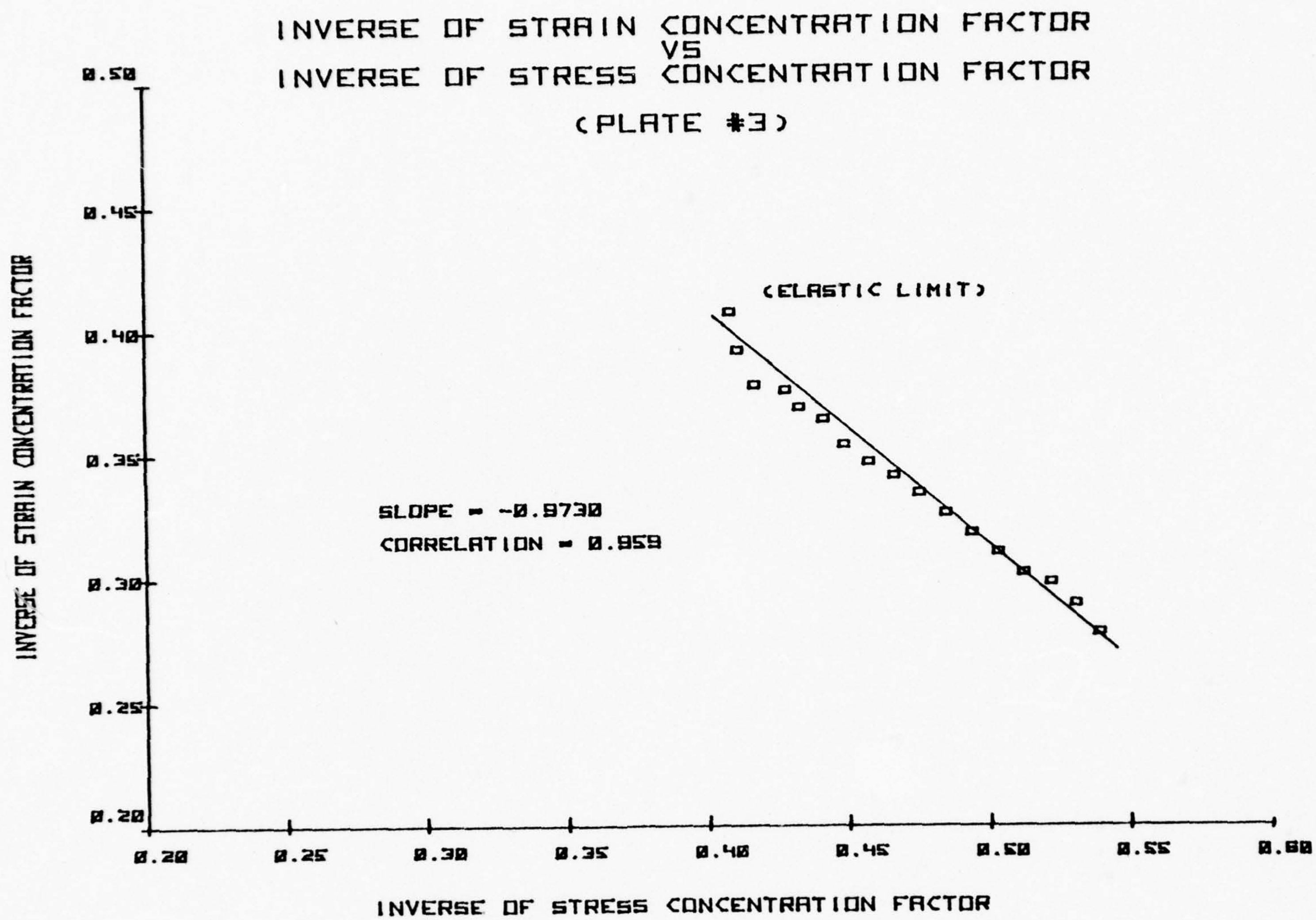

INVERSE OF STRAIN CONCENTRATION FACTOR
VS
INVERSE OF STRESS CONCENTRATION FACTOR
(PLATE #3)
(ELASTIC LIMIT)
SLOPE = -0.9730
CORRELATION = 0.959
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60
INVERSE OF STRAIN CONCENTRATION FACTOR
INVERSE OF STRESS CONCENTRATION FACTOR

FIGURE 31

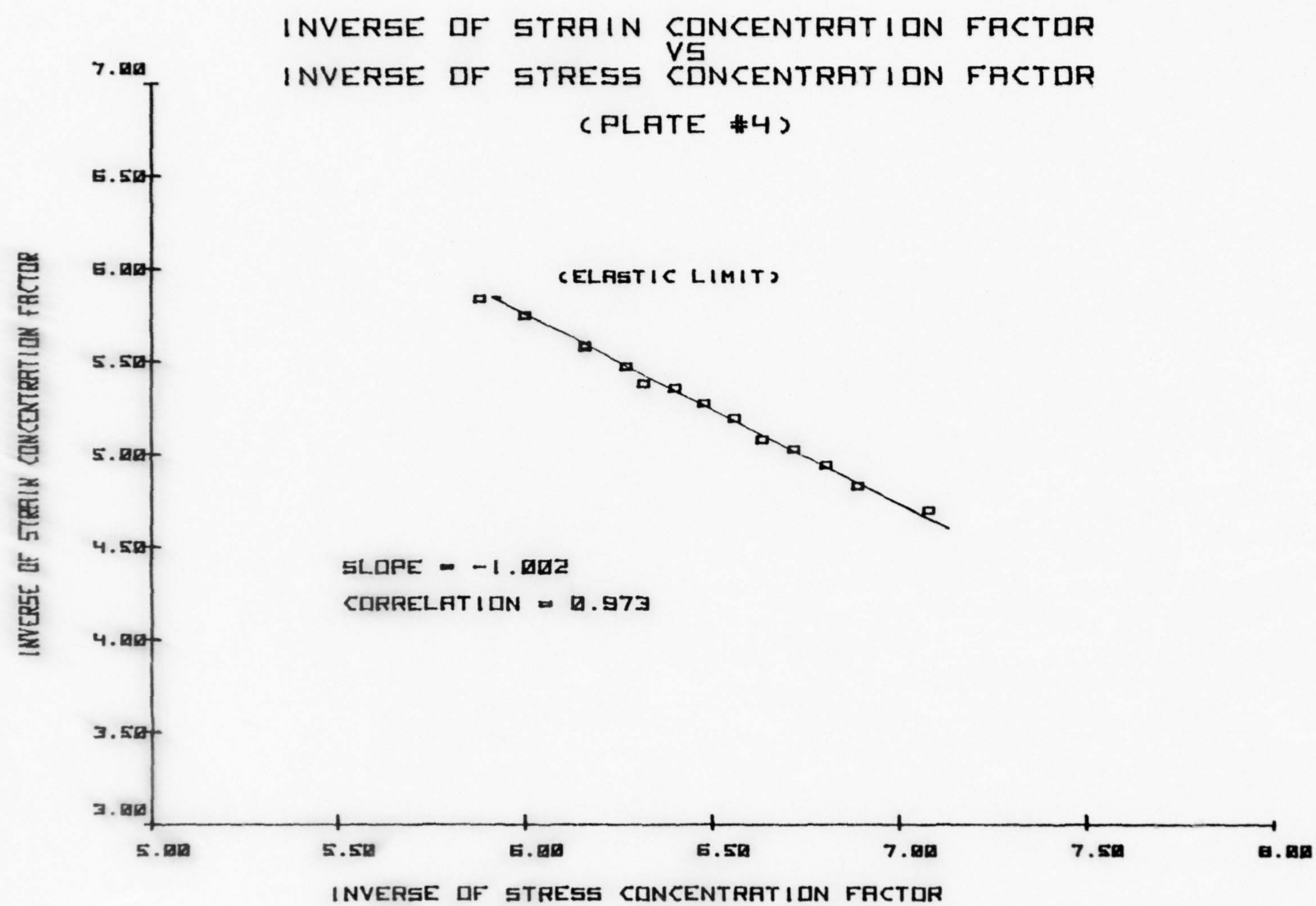

INVERSE OF STRAIN CONCENTRATION FACTOR
VS
INVERSE OF STRESS CONCENTRATION FACTOR
(PLATE #4)
(ELASTIC LIMIT)
SLOPE = -1.002
CORRELATION = 0.973
7.00
6.50
6.00
5.50
5.00
4.50
4.00
3.50
3.00
5.00
5.50
6.00
6.50
7.00
7.50
8.00
INVERSE OF STRAIN CONCENTRATION FACTOR
INVERSE OF STRESS CONCENTRATION FACTOR

FIGURE 32

as well as the computed slopes and correlation coefficients using a least squares polynomial regression of degree one. Figure 33 shows the relation of slope, b, to the far field elastic stress concentration factor.

The elastic limit in Figures 29-32 is at the point where the inverse of the strain concentration factor equals the inverse of the stress concentration factor. All data in the elastic range will, theoretically, be plotted at this point. Therefore, it can be shown that

$$(1/K_{\epsilon}\ (ff)) = (1/K_{t}\ (ff)) - b\ [(1/K_{\sigma}\ (ff)) - (1/K_{t}\ (ff))]$$

or

$$e/\epsilon = (1/K_{t}\ (ff)) - b\ [(S/\sigma) - (1/K_{t}\ (ff))]$$

Assuming as in the power curve fit method that stress is the product of an influence coefficient, E', and strain, then solving for stress, it can be shown that

$$\sigma = EeK_{t}\ (ff)[(b+(E'/E))/(b+1)]$$

It is obvious that if E is substituted for E' in the above equation, the elastic condition is satisfied.

Subroutine SOLVE2 of a data reduction program used the same influence coefficient concept as described previously in Table 6 of Appendix A and Figure 27. The scheme for calculating the notch root stress for a given input strain was the same as described in Figure 28.

Tabular results using this method are presented in Tables 8, 14, 20 and 26. Examination of the tabular data shows that the stresses calculated using the linear curve fit method

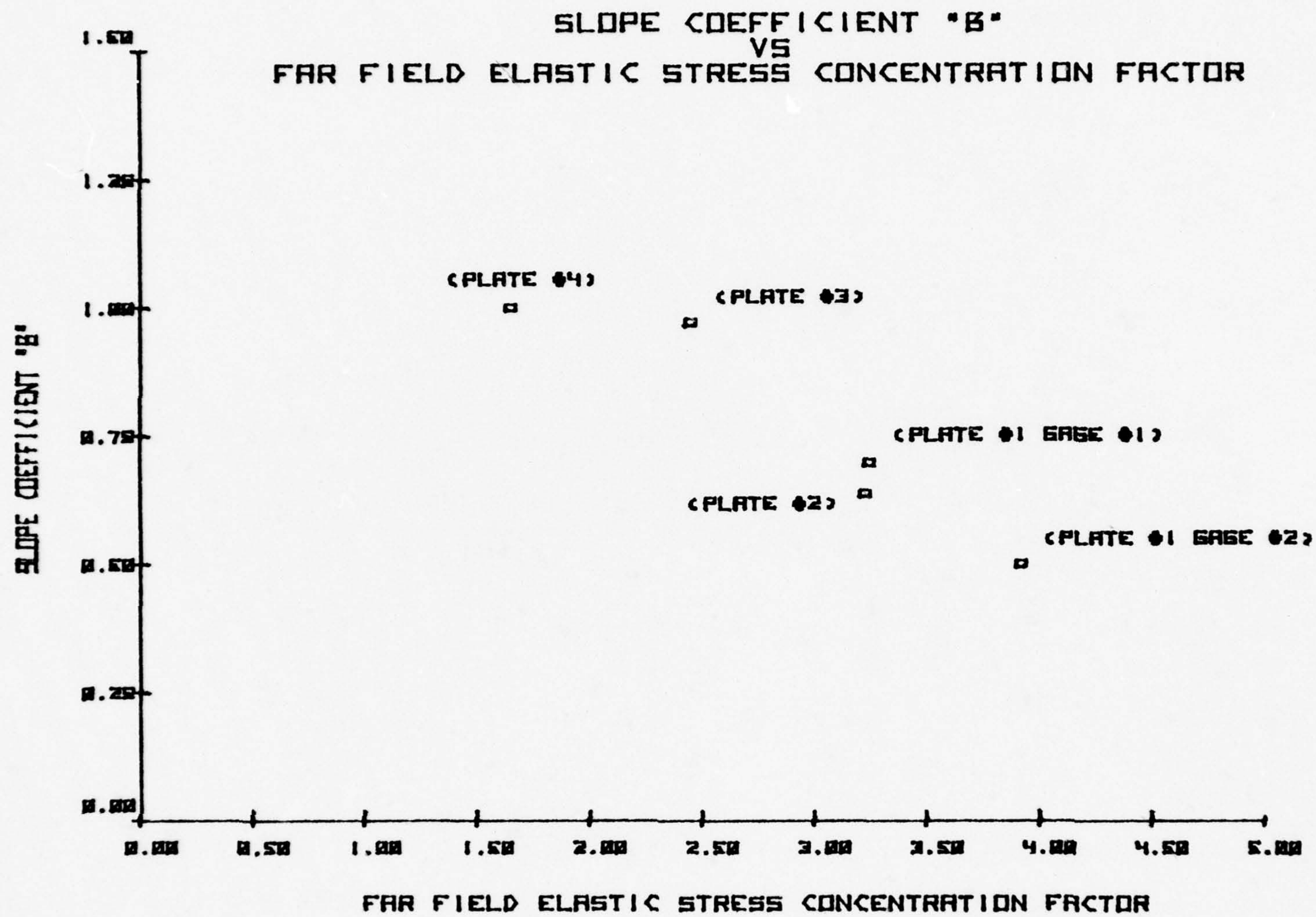

SLOPE COEFFICIENT "B"
VS
FAR FIELD ELASTIC STRESS CONCENTRATION FACTOR
SLOPE COEFFICIENT "B"
1.50
1.25
1.00
0.75
0.50
0.25
0.00
(PLATE #4)
(PLATE #3)
(PLATE #1 GAGE #1)
(PLATE #2)
(PLATE #1 GAGE #2)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
FAR FIELD ELASTIC STRESS CONCENTRATION FACTOR

FIGURE 33

differed by as much as ten percent from the actual stresses recorded in the notched specimen tests. It should be noted, however, that only one iteration was used in determining the coefficient, E', to use when calculating the notch root stress for a far field strain.

The relation between the slope factor and far field elastic stress concentration factor as shown in Figure 33 was not readily apparent and not considered further during this investigation.

V. CONCLUSIONS AND RECOMMENDATIONS

A. NEUBER'S RELATION

The results of the notched specimen tests indicate that Neuber's relation is in error by as much as ten percent when strains are less than one percent. As the strains at the notch root became more significant, Neuber's relation became less accurate with fifteen percent error at two percent strain and twenty percent at three percent strain. It can be concluded that methods of calculating local stress using Nueber's relation would be susceptible to the same inaccuracies.

B. FINITE ELEMENT ANALYSIS

The results of the finite element analysis of notched flat plates in plane stress using program ADINA correlated well with the results obtained in the notched specimen tests. The only limitation on program ADINA appears to be its modeling the element material in the plastic range in a bilinear stress-strain relationship. It is therefore recommended that element model number fifteen of program ADINA be developed in order to define the material more closely throughout the range of strains to be encountered in the area of the notch root.

C. DETERMINATION OF NOTCH ROOT STRESS FROM FAR FIELD STRAIN

The Heuristic analysis investigated in Section IV is simple to use and economical with respect to computer time

used to perform the calculations. The heuristic method is much more accurate in the nonlinear range than Neuber's relation for the notch geometries and material properties used in this investigation. In view of the computational requirements to process the input strain data, the heuristic method of calculating notch root stress is recommended for inclusion in reference 8, provided a four percent error is tolerable, and the concept is proven for other materials.

The power curve fit method of calculating the notch root stress was found to be in error by as much as fifteen percent. In addition, the fit of the curve to the stress and strain concentration factors data was poor, as shown in Table 27. In view of the poor fit of the data, and the increased computation time necessary to make this method useful, it is not recommended as a means of calculating notch root stress from far field strain.

The linear fit of the inverse of the stress and strain concentration factors was more accurate than the power curve fit method. Because of the good correlation coefficients determined while calculating the slope factor, b, it has been concluded that a refinement of the iteration scheme to determine the proper influence coefficient E' would produce results more accurate than the heuristic method.

In view of the above, it is recommended that an improved iteration scheme be developed to calculate notch root stress using the linear relation between the inverse of the stress and strain concentration factors. It is also recommended that further investigation be done to determine the slope

factor as a function of material and elastic stress concentration factor. Furthermore, if the computational time is deemed to be worth the accuracy, it is recommended that the linear fit of the inverse of the stress and strain concentration factors method be used to calculate the notch root stress in reference 8.

APPENDIX A

EXPERIMENTAL TEST DATA

TABLE 1

STRESS-STRAIN CURVE DATA

STRESS	STRAIN
0.0	0.0
7407.00	0.00071000
22222.00	0.00204000
29630.00	0.00281000
33333.00	0.00309000
37037.00	0.00347000
40741.00	0.00388000
44444.00	0.00417000
48148.00	0.00455000
51851.00	0.00493000
55555.00	0.00522000
59259.00	0.00566000
62963.00	0.00601000
66666.00	0.00653000
68519.00	0.00681000
70370.00	0.00704000
72222.00	0.00756000
74074.00	0.00807000
75926.00	0.00892000
76852.00	0.00955000
77778.00	0.01033000
79629.00	0.01290000
80555.00	0.01450000
81481.00	0.01725000
82407.00	0.02150000
84259.00	0.03660000
85185.00	0.04853000
84444.00	0.06314999

TABLE 2

DATA FOR TEST PLATE 1

RECORDED DATA

LOAD	STRAIN 1	STRAIN 2	STRAIN 3
1000.00	0.00020000	0.00040000	0.00008750
3000.00	0.00070000	0.00100000	0.00026250
5000.00	0.00130000	0.00170000	0.00043750
7000.00	0.00200000	0.00250000	0.00061250
9000.00	0.00250000	0.00310000	0.00078750
11000.00	0.00315000	0.00370000	0.00096250
13000.00	0.00375000	0.00450000	0.00114000
15000.00	0.00450000	0.00510000	0.00131250
17000.00	0.00500000	0.00580000	0.00148750
18000.00	0.00540000	0.00610000	0.00157500
19000.00	0.00570000	0.00650000	0.00166000
20000.00	0.00610000	0.00700000	0.00175000
21000.00	0.00650000	0.00750000	0.00184000
22000.00	0.00700000	0.00800000	0.00192500
23000.00	0.00750000	0.00850000	0.00201250
24000.00	0.00800000	0.00920000	0.00210000
25000.00	0.00860000	0.00980000	0.00218750
27500.00	0.01010000	0.01200000	0.00240000
29000.00	0.01125000	0.01270000	0.00253750
30000.00	0.01200000	0.01360000	0.00262500
31000.00	0.01300000	0.01450000	0.00271250
32000.00	0.01425000	0.01550000	0.00280000
33000.00	0.01470000	0.01650000	0.00289000
34000.00	0.01565000	0.01750000	0.00297500
35000.00	0.01660000	0.01850000	0.00306000
36000.00	0.01775000	0.01970000	0.00315000
37000.00	0.01900000	0.02100000	0.00323750
38000.00	0.02000000	0.02200000	0.00332500
39000.00	0.02150000	0.02350000	0.00341250
40000.00	0.02270000	0.02480000	0.00350000
41000.00	0.02400000	0.02630000	0.00358750
42000.00	0.02540000	0.02780000	0.00367500
42500.00	0.02650000	0.02810000	0.00372000
43000.00	0.02685000	0.02950000	0.00376000
43500.00	0.02760000	0.03025000	0.00380000
44500.00	0.02860000	0.03190000	0.00385000
45500.00	0.03085000	0.03375000	0.00398000
46000.00	0.03170000	0.03450000	0.00402500
46500.00	0.03270000	0.03550000	0.00407000
47000.00	0.03360000	0.03650000	0.00411300

TABLE 3

DATA FOR TEST PLATE 1

CALCULATED STRESSES

LOAD NO.	STRESS 1	STRESS 2	STRESS 3
1	2040.93	4123.93	886.95
2	7300.45	10564.13	2687.92
3	13927.23	18450.39	4518.18
4	21785.23	26621.02	6369.48
5	26621.02	33436.01	8238.19
6	33945.03	39090.82	10149.37
7	39533.71	47660.69	12125.27
8	47660.69	54038.90	14068.53
9	52655.73	60786.64	16049.94
10	57131.38	63648.68	17040.29
11	59663.62	66462.88	18000.00
12	63648.68	70157.44	19011.95
13	66462.88	72007.06	20017.79
14	70157.44	73826.44	20960.51
15	72007.06	75213.50	21921.96
16	73826.44	76359.31	22859.28
17	75401.88	77179.69	23738.41
18	77545.88	79048.06	25716.88
19	78519.38	79503.00	26962.83
20	79048.06	80067.44	27776.06
21	79691.88	80555.00	28624.20
22	80435.31	80956.19	29523.29
23	80642.44	81278.69	30632.99
24	81009.06	81543.81	31858.23
25	81307.38	81792.13	32998.48
26	81606.56	82070.81	33945.03
27	81911.88	82326.63	34814.50
28	82135.00	82480.81	35662.36
29	92407.00	82696.06	36495.01
30	82582.44	82875.25	37316.09
31	82765.75	83074.06	38103.46
32	82955.75	83265.06	38871.38
33	83100.00	83302.31	39267.17
34	83145.00	83472.69	39623.26
35	83240.00	83561.56	39985.94
36	83363.88	83751.63	40452.34
37	83631.50	83956.81	41956.42
38	83729.00	84037.88	42592.41
39	83841.38	84144.13	43228.47
40	83940.50	84248.63	43800.11

TABLE 4

DATA FOR TEST PLATE 1

STRESSES AND STRAINS BASED ON LOAD
(NOMINAL AND APPLIED)

LOAD NO.	NOM STRESS	NOM STRAIN	APP STRESS	APP STRAIN
1	1291.99	0.00012217	925.93	0.00008756
2	3875.97	0.00036651	2777.78	0.00026267
3	6459.95	0.00061086	4629.63	0.00043778
4	9043.93	0.00085520	6481.48	0.00061289
5	11627.91	0.00109954	8333.33	0.00078801
6	14211.88	0.00134389	10185.18	0.00096312
7	16795.86	0.00158823	12037.04	0.00113823
8	19379.84	0.00183257	13888.89	0.00131334
9	21963.82	0.00207692	15740.74	0.00148846
10	23255.81	0.00219909	16666.66	0.00157601
11	24547.80	0.00232126	17592.59	0.00166357
12	25839.79	0.00244343	18518.52	0.00175112
13	27131.78	0.00256560	19444.45	0.00183868
14	28423.77	0.00268777	20370.37	0.00192624
15	29715.76	0.00280994	21296.30	0.00201379
16	31007.75	0.00293212	22222.22	0.00210135
17	32299.74	0.00305429	23148.15	0.00218891
18	35529.71	0.00335972	25462.96	0.00240780
19	37467.70	0.00354297	26851.85	0.00253913
20	38759.69	0.00366514	27777.78	0.00262669
21	40051.68	0.00378732	28703.70	0.00271424
22	41343.67	0.00390949	29629.63	0.00280180
23	42635.66	0.00403166	30555.55	0.00288936
24	43927.65	0.00415383	31481.48	0.00297691
25	45219.64	0.00427600	32407.41	0.00306447
26	46511.63	0.00439817	33333.33	0.00315202
27	47803.62	0.00452035	34259.26	0.00323958
28	49095.61	0.00464252	35185.19	0.00332714
29	50387.59	0.00476469	36111.11	0.00341469
30	51679.59	0.00488686	37037.04	0.00350225
31	52971.57	0.00500903	37962.96	0.00358981
32	54263.57	0.00513120	38888.89	0.00367736
33	54909.56	0.00519229	39351.85	0.00372114
34	55555.55	0.00525337	39814.82	0.00376492
35	56201.55	0.00531446	40277.78	0.00380870
36	57493.54	0.00543663	41203.70	0.00389625
37	58785.53	0.00555880	42129.63	0.00398381
38	59431.52	0.00561989	42592.59	0.00402759
39	60077.52	0.00568097	43055.56	0.00407136
40	60723.51	0.00574206	43518.52	0.00411514

TABLE 5

HEURISTIC DATA FOR PLATE 1

LOAD NO.	HEU STRESS	ACT STRESS	RATIO
1	3236.41	3082.43	0.9524215
2	9963.06	8932.29	0.8965405
3	17051.73	16188.81	0.9493943
4	23921.98	24203.13	1.0117521
5	29936.44	30028.51	1.0030756
6	37010.91	36517.91	0.9866796
7	43602.05	43597.19	0.9998885
8	49882.90	50849.78	1.0193825
9	56802.45	56721.16	0.9985688
10	59392.75	60390.25	1.0167942
11	62790.42	63063.22	1.0043440
12	65118.55	66903.00	1.0273962
13	67259.94	69234.94	1.0293636
14	69619.06	71991.94	1.0340834
15	71129.63	73610.25	1.0348740
16	72239.56	75092.88	1.0394974
17	73393.19	76290.25	1.0394726
18	75520.56	78296.94	1.0367622
19	76269.94	79011.19	1.0359411
20	76726.88	79557.75	1.0368948
21	77141.38	80123.44	1.0386562
22	77530.56	80695.75	1.0408249
23	77840.31	80960.56	1.0400848
24	78104.69	81276.44	1.0406084
25	78354.38	81549.75	1.0407810
26	78591.19	81838.69	1.0413208
27	78816.81	82119.25	1.0418997
28	79033.06	82307.88	1.0414352
29	79241.75	82551.50	1.0417671
30	79444.69	82728.81	1.0413380
31	79643.56	82919.88	1.0411367
32	79842.44	83110.38	1.0409298
33	79941.44	83201.13	1.0407753
34	80039.13	83308.81	1.0408506
35	80134.69	83400.75	1.0407562
36	80316.56	83557.75	1.0403547
37	80480.94	83794.13	1.0411673
38	80554.69	83883.44	1.0413227
39	80623.94	83992.75	1.0417833
40	80690.88	84094.56	1.0421810

TABLE 6

DATA FOR TEST PLATE 1

STRESS AND E PRIME DATA

STRESS	E PRIME
7407.00	10575213.0
22222.00	10575213.0
29630.00	10575213.0
33333.00	10575213.0
37037.00	10575213.0
40741.00	10575213.0
44444.00	10575213.0
48148.00	10575213.0
51851.00	10575213.0
55555.00	10575213.0
59259.00	10469792.0
62963.00	10476373.0
66666.00	10209191.0
68519.00	10061529.0
70370.00	9995741.0
72222.00	9553174.0
74074.00	9178934.0
75926.00	8511884.0
76852.00	8047331.0
77778.00	7529332.0
79629.00	6172791.0
80555.00	5555517.0
81481.00	4723536.0
82407.00	3832883.0
84259.00	2302158.0
85185.00	1755306.0

TABLE 7

EXPONENTIAL CURVE FIT DATA FOR TEST PLATE 1

CALCULATED	ACTUAL	RATIO	E PRIME
3333.24	3082.43	1.081367	10575213.0
9999.71	8932.29	1.119501	10575213.0
16666.19	16188.81	1.029488	10575213.0
23332.67	24203.13	0.964035	10575213.0
29999.15	30028.51	0.999022	10575213.0
36665.62	36517.91	1.004045	10575213.0
43332.10	43597.19	0.993920	10575213.0
49998.58	50849.78	0.983261	10575213.0
56303.92	56721.16	0.992644	10521128.0
59254.07	60390.25	0.981186	10469840.0
62636.71	63063.22	0.993237	10481968.0
64639.37	66903.00	0.966165	10316608.0
66667.31	69234.94	0.962914	10169520.0
68691.00	71991.94	0.954148	10035024.0
70134.75	73610.25	0.952785	9846504.0
72439.75	75092.88	0.964669	9765992.0
73951.19	76290.25	0.969340	9609304.0
77823.94	78296.94	0.993959	9273992.0
77762.31	79011.19	0.984194	8881480.0
81106.31	79557.75	1.019464	8940216.0
80709.69	80123.44	1.007317	8673840.0
78747.81	80695.75	0.975861	8290487.0
84568.06	80960.56	1.044559	8564464.0
84270.50	81276.44	1.036838	8338224.0
81215.81	81549.75	0.995905	7908838.0
89169.50	81838.69	1.089576	8333866.0
91490.25	82119.25	1.114114	8322467.0
93155.75	82307.88	1.131796	8265074.0
94663.56	82551.50	1.146721	8199579.0
96092.38	82728.81	1.161534	8131876.0
98106.63	82919.88	1.183149	8106155.0
98045.88	83110.38	1.179707	7947037.0
97603.19	83201.13	1.173099	7843431.0
97457.00	83308.81	1.169827	7760848.0
97178.75	83400.75	1.165202	7671592.0
94533.94	83557.75	1.131360	7368115.0
89550.44	83794.13	1.068695	6930264.0
85918.00	83883.44	1.024254	6645326.0
81616.50	83992.75	0.971709	6322054.0
106940.19	84094.56	1.271666	7785244.0

TABLE 8

INVERSE RELATION CURVE FIT DATA FOR PLATE 1

CALCULATED	ACTUAL	RATIO	E PRIME
3333.33	3082.43	1.08139706	10575213.0
9999.98	8932.29	1.11953163	10575213.0
16666.64	16188.81	1.02951527	10575213.0
23333.31	24203.13	0.96406180	10575213.0
29999.96	30028.51	0.99904931	10575213.0
36666.63	36517.91	1.00407219	10575213.0
43333.28	43597.19	0.99394667	10575213.0
49999.95	50849.78	0.98328739	10575213.0
56483.56	56721.16	0.99581116	10517824.0
59225.09	60390.25	0.98070610	10345792.0
62969.75	63063.22	0.99851775	10473240.0
65492.63	66903.00	0.97891915	10262360.0
68060.94	69234.94	0.98304319	10083112.0
70125.56	71991.94	0.97407520	9798136.0
72301.69	73610.25	0.98222309	9563760.0
73892.00	75092.88	0.98400813	9218848.0
75434.31	76290.25	0.98878050	8891288.0
78456.06	78296.94	1.00203228	8014968.0
81636.13	79011.19	1.03322220	7812931.0
82656.69	79557.75	1.03895187	7494142.0
81766.81	80123.44	1.02050972	6867461.0
84516.13	80695.75	1.04734230	6886058.0
82465.81	80960.56	1.01859188	6128375.0
87972.19	81276.44	1.08238220	6599799.0
86415.25	81549.75	1.05966282	5968721.0
83493.50	81838.69	1.02021980	5170653.0
91745.38	82119.25	1.11722088	6025206.0
89704.50	82307.88	1.08986473	5391190.0
86649.56	82551.50	1.04964161	4651119.0
99399.13	82728.81	1.20150471	6053844.0
100299.69	82919.88	1.20959759	5847886.0
101067.94	83110.38	1.21606827	5634937.0
100872.25	83201.13	1.21238995	5459513.0
100324.38	83308.81	1.20424652	5244524.0
99552.00	83400.75	1.19365788	5006966.0
96550.31	83557.75	1.15549183	4373377.0
93148.38	83794.13	1.11163330	3720762.0
90520.13	83883.44	1.07911777	3297645.0
87869.94	83992.75	1.04616070	2881128.0
85556.19	84094.56	1.01738071	2511616.0

TABLE 9

DATA FOR TEST PLATE 2

RECORDED DATA

LOAD	STRAIN 1	STRAIN 2	STRAIN 3
3000.00	0.00080000	0.00090000	0.00026200
6000.00	0.00150000	0.00175000	0.00052400
9000.00	0.00250000	0.00255000	0.00073600
12000.00	0.00350000	0.00350000	0.00104800
15000.00	0.00415000	0.00425000	0.00131000
16000.00	0.00450000	0.00450000	0.00139000
17000.00	0.00475000	0.00490000	0.00149000
18000.00	0.00500000	0.00510000	0.00157000
19000.00	0.00530000	0.00550000	0.00166000
20000.00	0.00555000	0.00570000	0.00175000
21000.00	0.00590000	0.00600000	0.00183000
22000.00	0.00625000	0.00650000	0.00192000
23000.00	0.00650000	0.00690000	0.00201000
24000.00	0.00700000	0.00740000	0.00210000
25000.00	0.00740000	0.00780000	0.00218000
26000.00	0.00770000	0.00795000	0.00277000
27000.00	0.00815000	0.00845000	0.00236000
28000.00	0.00860000	0.00950000	0.00244000
29000.00	0.00905000	0.01000000	0.00253000
30000.00	0.00955000	0.00955000	0.00261000
31000.00	0.01010000	0.01010000	0.00269500
32000.00	0.01070000	0.01070000	0.00278000
33000.00	0.01130000	0.01130000	0.00287000
34000.00	0.01200000	0.01200000	0.00295000
35000.00	0.01260000	0.01260000	0.00304000
36000.00	0.01280000	0.01280000	0.00312000
37000.00	0.01400000	0.01400000	0.00321000
38000.00	0.01480000	0.01480000	0.00331000
39000.00	0.01560000	0.01560000	0.00340000
40000.00	0.01650000	0.01650000	0.00349000
41000.00	0.01745000	0.01745000	0.00359000
42000.00	0.01845000	0.01845000	0.00368000
42500.00	0.01895000	0.01895000	0.00373000
43000.00	0.01950000	0.01950000	0.00377000
43500.00	0.02000000	0.02000000	0.00382000
44000.00	0.02055000	0.02055000	0.00386600
44500.00	0.02110000	0.02110000	0.00391000
45000.00	0.02180000	0.02180000	0.00396000
45500.00	0.02250000	0.02250000	0.00400000

TABLE 10

DATA FOR TEST PLATE 2

CALCULATED STRESSES

LOAD NO.	STRESS 1	STRESS 2	STRESS 3
1	8373.20	9461.90	2682.73
2	17322.86	19011.95	5431.13
3	26621.02	27077.47	8222.01
4	37316.09	37316.09	11097.28
5	44237.11	45223.91	14040.27
6	47660.69	47660.69	14945.55
7	50096.92	51558.62	16078.25
8	52655.73	54038.90	16983.74
9	56311.29	57901.18	18000.00
10	58295.82	59663.62	19011.95
11	61921.43	62883.39	19906.39
12	64738.75	66462.88	20905.28
13	66462.88	69292.06	21894.64
14	70157.44	71655.19	22859.28
15	71655.19	73100.13	23665.06
16	72732.75	73646.94	29208.29
17	74339.13	75111.31	25354.25
18	75401.98	76786.13	26078.18
19	76130.13	77429.44	26894.23
20	76852.00	76852.00	27634.61
21	77545.88	77545.98	28451.01
22	78090.94	78090.94	29312.45
23	78556.38	78556.38	30359.89
24	79048.06	79048.06	31495.30
25	79439.50	79439.50	32751.29
26	79566.13	79566.13	33640.79
27	80301.88	80301.88	34543.88
28	80684.81	80684.81	35518.27
29	80991.63	80991.63	36376.75
30	81278.69	81278.69	37223.70
31	81531.25	81531.25	38125.55
32	81779.94	81779.94	38915.20
33	81900.06	81900.06	39355.71
34	82026.63	82026.63	39713.21
35	82135.00	82135.00	40170.54
36	82245.06	82245.06	40605.38
37	82343.63	82343.63	41059.58
38	82451.44	82451.44	41684.00
39	82553.63	82553.63	42236.54

TABLE 11

DATA FOR TEST PLATE 2

STRESSES AND STRAINS BASED ON LOAD
(NOMINAL AND APPLIED)

LOAD NO.	NOM STRESS	NOM STRAIN	APP STRESS	APP STRAIN
1	3875.97	0.00036651	2777.78	0.00026267
2	7751.94	0.00073303	5555.55	0.00052534
3	11627.91	0.00109954	8333.33	0.00078801
4	15503.88	0.00146606	11111.11	0.00105067
5	19379.84	0.00183257	13888.89	0.00131334
6	20671.83	0.00195474	14814.81	0.00140090
7	21963.82	0.00207692	15740.74	0.00148846
8	23255.81	0.00219909	16666.66	0.00157601
9	24547.80	0.00232126	17592.59	0.00166357
10	25839.79	0.00244343	18518.52	0.00175112
11	27131.78	0.00256560	19444.45	0.00183868
12	28423.77	0.00268777	20370.37	0.00192624
13	29715.76	0.00280994	21296.30	0.00201379
14	31007.75	0.00293212	22222.22	0.00210135
15	32299.74	0.00305429	23148.15	0.00218891
16	33591.73	0.00317646	24074.07	0.00227646
17	34883.72	0.00329863	25000.00	0.00236402
18	36175.71	0.00342080	25925.93	0.00245157
19	37467.70	0.00354297	26851.85	0.00253913
20	38759.69	0.00366514	27777.78	0.00262669
21	40051.68	0.00378732	28703.70	0.00271424
22	41343.67	0.00390949	29629.63	0.00280180
23	42635.66	0.00403166	30555.55	0.00288936
24	43927.65	0.00415383	31481.48	0.00297691
25	45219.64	0.00427600	32407.41	0.00306447
26	46511.63	0.00439817	33333.33	0.00315202
27	47803.62	0.00452035	34259.26	0.00323958
28	49095.61	0.00464252	35185.19	0.00332714
29	50387.59	0.00476469	36111.11	0.00341469
30	51679.59	0.00488686	37037.04	0.00350225
31	52971.57	0.00500903	37962.96	0.00358981
32	54263.57	0.00513120	38888.89	0.00367736
33	54909.56	0.00519229	39351.85	0.00372114
34	55555.55	0.00525337	39814.82	0.00376492
35	56201.55	0.00531446	40277.78	0.00380870
36	56847.54	0.00537555	40740.74	0.00385247
37	57493.54	0.00543663	41203.70	0.00389625
38	58139.54	0.00549772	41666.67	0.00394003
39	58785.53	0.00555880	42129.63	0.00398381

TABLE 12

HEURISTIC DATA FOR PLATE 2

LOAD NO.	HEU STRESS	ACT STRESS	RATIO
1	8907.14	8917.55	1.0011683
2	18432.69	18167.40	0.9856077
3	27055.80	26849.25	0.9923657
4	36346.94	37316.06	1.0266628
5	45185.59	44730.50	0.9899283
6	47944.68	47660.69	0.9940766
7	50703.11	50827.75	1.0024576
8	53972.40	53347.31	0.9884134
9	56961.83	57106.22	1.0025339
10	59272.75	58979.72	0.9950563
11	62381.77	62402.41	1.0003300
12	64579.24	65600.81	1.0158186
13	66534.94	67877.44	1.0201769
14	68409.19	70906.31	1.0365019
15	70507.50	72377.63	1.0265236
16	71515.06	73189.81	1.0234175
17	72523.56	74725.19	1.0303574
18	73560.19	76094.00	1.0344448
19	74516.88	76779.75	1.0303669
20	75197.81	76852.00	1.0219975
21	75696.69	77545.88	1.0244284
22	76143.00	78090.94	1.0255823
23	76566.50	78556.38	1.0259886
24	76949.13	79048.06	1.0272760
25	77315.75	79439.50	1.0274677
26	77644.00	79566.13	1.0247555
27	77902.06	80301.88	1.0308046
28	78137.00	80684.81	1.0326061
29	78360.31	80991.63	1.0335739
30	78573.25	81278.69	1.0344315
31	78777.06	81531.25	1.0349617
32	78973.06	81779.94	1.0355415
33	79068.56	81900.06	1.0358105
34	79162.56	82026.63	1.0361786
35	79255.25	82135.00	1.0363350
36	79346.81	82245.06	1.0365257
37	79437.44	82343.63	1.0365839
38	79527.19	82451.44	1.0367699
39	79616.25	82553.63	1.0368938

TABLE 13

EXPONENTIAL CURVE FIT DATA FOR TEST PLATE 2

CALCULATED	ACTUAL	RATIO	E PRIME
8980.22	8917.55	1.007028	10575213.0
17960.45	18167.40	0.988608	10575213.0
26940.68	26849.25	1.003405	10575213.0
35920.90	37316.06	0.962612	10575213.0
44901.13	44730.50	1.003814	10575213.0
47894.54	47660.69	1.004906	10575213.0
50387.95	50827.75	1.001184	10575213.0
53881.35	53347.31	1.010010	10575213.0
56310.89	57106.22	0.986073	10522144.0
58773.86	58979.72	0.996510	10477192.0
61799.25	62402.41	0.990334	10484688.0
63138.20	65600.81	0.962461	10352800.0
65375.59	67877.44	0.963142	10302664.0
66829.19	70906.31	0.942500	10196312.0
68184.00	72377.63	0.942059	10090152.0
69937.75	73189.81	0.955567	10019984.0
70971.25	74725.19	0.949763	9904200.0
72180.69	76094.00	0.948573	9807360.0
73365.19	76779.75	0.955528	9714608.0
74866.88	76852.00	0.974169	9648048.0
76646.53	77545.88	0.988404	9603024.0
75090.06	78090.94	0.961572	9353136.0
79081.56	78556.38	1.006685	9452776.0
80223.38	79048.06	1.014868	9379080.0
81242.94	79439.50	1.022701	9301968.0
82986.13	79566.13	1.042983	9269576.0
81423.81	80301.88	1.013971	9055104.0
80038.63	80684.81	0.991991	8857008.0
75945.06	80991.63	0.937690	8513272.0
87842.50	81278.69	1.080756	9045480.0
87266.00	81531.25	1.070337	8903968.0
85543.31	81779.94	1.046018	8708328.0
84814.50	81900.06	1.035584	8619192.0
83322.19	82026.63	1.015794	8492152.0
80874.50	82135.00	0.984653	8316697.0
77713.88	82245.06	0.944906	8104327.0
92933.25	82343.63	1.129602	9818984.0
93369.31	82451.44	1.132416	8790184.0
94337.44	82553.63	1.142741	8786888.0

TABLE 14

INVERSE RELATION CURVE FIT DATA FOR PLATE 2

CALCULATED	ACTUAL	RATIO	E PRIME
8980.60	8917.55	1.00706959	10575213.0
17961.21	18167.40	0.98865020	10575213.0
26941.82	26849.25	1.00344753	10575213.0
35922.43	37316.06	0.96265322	10575213.0
44903.04	44730.50	1.00385666	10575213.0
47896.58	47660.69	1.00494862	10575213.0
50890.11	50827.75	1.00122643	10575213.0
53883.65	53347.31	1.01005363	10575213.0
56680.84	57106.22	0.99255115	10515344.0
59087.15	58979.72	1.00182152	10348248.0
62529.36	62402.41	1.00203419	10482832.0
64787.00	65600.81	0.98759443	10293256.0
67082.50	67877.44	0.98828858	10129712.0
69544.94	70906.31	0.98080033	10020080.0
71363.69	72377.63	0.98599100	9770056.0
72775.69	73189.81	0.99434173	9448656.0
74243.69	74725.19	0.99355638	9163088.0
75582.19	76094.00	0.99327391	8871112.0
76939.56	76779.75	1.00208092	8603040.0
76901.44	76852.00	1.00064278	8083377.0
78376.31	77545.88	1.01070881	7879965.0
81335.19	78090.94	1.04154396	7957919.0
82500.25	78556.38	1.05020428	7716258.0
82784.88	79048.06	1.04727173	7338794.0
81457.19	79439.50	1.02539825	6716062.0
84768.94	79566.13	1.06538963	6874462.0
82894.50	80301.88	1.03228569	6212332.0
88593.25	80684.81	1.09801579	6739531.0
87644.00	80991.63	1.08213615	6252247.0
85073.88	81278.69	1.04669285	5554581.0
81859.38	81531.25	1.00402451	4799902.0
92136.50	81779.94	1.12663937	5942002.0
91362.25	81900.06	1.11553288	5686965.0
90013.63	82026.63	1.09737015	5360475.0
88480.19	82135.00	1.07725239	5016880.0
87195.13	82245.06	1.06018639	4713799.0
85064.00	82343.63	1.03303623	4307390.0
82600.94	82451.44	1.00181293	3367282.0
100709.81	82553.63	1.21993160	6055993.0

TABLE 15

DATA FOR TEST PLATE 3

RECORDED DATA

LOAD	STRAIN 1	STRAIN 2	STRAIN 3
4000.00	0.00100000	0.00080000	0.00033000
8000.00	0.00175000	0.00155000	0.00070000
12000.00	0.00260000	0.00245000	0.00105000
15000.00	0.00330000	0.00300000	0.00130000
20000.00	0.00450000	0.00410000	0.00172000
24000.00	0.00530000	0.00500000	0.00200000
26500.00	0.00590000	0.00550000	0.00230000
28500.00	0.00640000	0.00600000	0.00250000
30500.00	0.00700000	0.00660000	0.00273000
31500.00	0.00725000	0.00695000	0.00280000
32500.00	0.00755000	0.00747000	0.00289000
33500.00	0.00790000	0.00755000	0.00295000
34000.00	0.00805000	0.00775000	0.00301000
34500.00	0.00825000	0.00800000	0.00307000
35000.00	0.00850000	0.00810000	0.00313000
35500.00	0.00860000	0.00830000	0.00319000
36000.00	0.00880000	0.00850000	0.00326000
36500.00	0.00910000	0.00875000	0.00332000
37000.00	0.00930000	0.00900000	0.00338000
37500.00	0.00950000	0.00920000	0.00344000
38000.00	0.00970000	0.00945000	0.00350000
38500.00	0.00990000	0.00965000	0.00353000
39000.00	0.01010000	0.00990000	0.00356000
39500.00	0.01030000	0.01015000	0.00359000
40000.00	0.01050000	0.01045000	0.00361000
40500.00	0.01080000	0.01060000	0.00364000
41000.00	0.01110000	0.01090000	0.00367000
41500.00	0.01140000	0.01120000	0.00370000
42000.00	0.01160000	0.01150000	0.00373000
42500.00	0.01200000	0.01170000	0.00380000
43000.00	0.01225000	0.01200000	0.00387000
43500.00	0.01260000	0.01220000	0.00395000
44000.00	0.01300000	0.01250000	0.00402000
44500.00	0.01285000	0.01285000	0.00405000
45000.00	0.01320000	0.01320000	0.00408000
45500.00	0.01350000	0.01350000	0.00441000
46000.00	0.01390000	0.01390000	0.00414000
46500.00	0.01425000	0.01425000	0.00417000
47000.00	0.01480000	0.01480000	0.00420000

TABLE 16

DATA FOR TEST PLATE 3

CALCULATED STRESSES

LOAD NO.	STRESS 1	STRESS 2	STRESS 3
1	10564.13	8373.20	3390.86
2	19011.95	16757.51	7300.45
3	27540.84	26168.48	11119.55
4	35421.95	32213.81	13927.23
5	47660.69	43633.10	18675.22
6	56311.29	52655.73	21785.23
7	61921.43	57901.18	24804.50
8	65782.19	62883.39	26621.02
9	70157.44	67133.13	29312.45
10	71130.81	69760.75	29523.29
11	72185.88	71900.88	30632.99
12	73465.81	72195.88	31495.30
13	74003.75	72916.44	32352.53
14	74631.88	73826.44	33115.23
15	75213.50	74176.88	33742.59
16	75401.88	74763.88	34345.59
17	75736.25	75213.50	35034.33
18	76207.38	75656.13	35614.38
19	76506.94	76052.13	36187.11
20	76786.13	76359.31	36754.59
21	77048.25	76718.56	37316.09
22	77306.38	76982.69	37589.85
23	77545.88	77306.38	37859.32
24	77751.13	77601.00	38125.55
25	77924.50	77881.88	38301.75
26	78171.88	78008.50	38564.89
27	78406.44	78251.44	38827.57
28	78629.63	78482.00	39090.82
29	78772.88	78701.75	39355.71
30	79048.06	78843.00	39985.94
31	79213.75	79048.06	40643.95
32	79439.50	79180.94	41551.81
33	79691.88	79375.63	42521.03
34	79597.56	79597.56	42948.28
35	79818.19	79818.19	43365.84
36	80006.06	80006.06	46783.51
37	80245.31	80245.31	44125.34
38	80435.31	80435.31	44444.00
39	80684.81	80684.81	44736.47

TABLE 17

DATA FOR TEST PLATE 3

STRESSES AND STRAINS BASED ON LOAD
(NOMINAL AND APPLIED)

LOAD NO.	NOM STRESS	NOM STRAIN	APP STRESS	APP STRAIN
1	4444.44	0.00042027	3703.70	0.00035022
2	8888.89	0.00084054	7407.41	0.00070045
3	13333.33	0.00126081	11111.11	0.00105067
4	16666.66	0.00157601	13888.89	0.00131334
5	22222.22	0.00210135	18518.52	0.00175112
6	26666.66	0.00252162	22222.22	0.00210135
7	29444.44	0.00278429	24537.04	0.00232024
8	31666.66	0.00299442	26388.89	0.00249535
9	33888.89	0.00320456	28240.74	0.00267047
10	35000.00	0.00330963	29166.67	0.00275802
11	36111.11	0.00341469	30092.59	0.00284558
12	37222.22	0.00351976	31018.52	0.00293313
13	37777.78	0.00357229	31481.48	0.00297691
14	38333.33	0.00362483	31944.45	0.00302069
15	38888.89	0.00367736	32407.41	0.00306447
16	39444.45	0.00372990	32870.37	0.00310825
17	40000.00	0.00378243	33333.33	0.00315202
18	40555.55	0.00383496	33796.30	0.00319580
19	41111.11	0.00388750	34259.26	0.00323958
20	41666.66	0.00394003	34722.22	0.00328336
21	42222.22	0.00399256	35185.19	0.00332714
22	42777.78	0.00404510	35648.15	0.00337092
23	43333.33	0.00409763	36111.11	0.00341469
24	43888.89	0.00415016	36574.07	0.00345847
25	44444.45	0.00420270	37037.04	0.00350225
26	45000.00	0.00425523	37500.00	0.00354603
27	45555.55	0.00430777	37962.96	0.00358981
28	46111.11	0.00436030	38425.93	0.00363358
29	46666.66	0.00441283	38888.89	0.00367736
30	47222.22	0.00446537	39351.85	0.00372114
31	47777.78	0.00451790	39814.82	0.00376492
32	48333.33	0.00457044	40277.78	0.00380870
33	48888.89	0.00462297	40740.74	0.00385247
34	49444.45	0.00467550	41203.70	0.00389625
35	50000.00	0.00472803	41666.67	0.00394003
36	50555.55	0.00478057	42129.63	0.00398381
37	51111.11	0.00483310	42592.59	0.00402759
38	51666.67	0.00488564	43055.56	0.00407136
39	52222.22	0.00493817	43518.52	0.00411514

TABLE 18

HEURISTIC DATA FOR PLATE 3

LOAD NO.	HEJ STRESS	ACT STRESS	RATIO
1	9000.36	9468.67	1.0520325
2	18625.12	17384.73	0.9602475
3	27292.46	26854.66	0.9839589
4	34609.42	33817.88	0.9771292
5	45602.67	45646.88	1.0009689
6	54679.80	54483.50	0.9964100
7	59484.39	59911.28	1.0071764
8	63735.27	64332.78	1.0093746
9	66736.88	68645.25	1.0285950
10	68150.75	70445.75	1.0336752
11	69927.44	72043.38	1.0302582
12	70896.44	72825.31	1.0272131
13	71274.81	73460.06	1.0306587
14	71649.19	74229.13	1.0360079
15	72026.63	74695.19	1.0370493
16	72413.31	75082.88	1.0368652
17	72805.94	75474.88	1.0366573
18	73199.75	75931.75	1.0373220
19	73590.56	76279.50	1.0365391
20	73974.13	76572.69	1.0351276
21	74335.44	76883.38	1.0342760
22	74648.71	77144.50	1.0334337
23	74918.63	77426.13	1.0334692
24	75153.88	77676.06	1.0335598
25	75361.50	77903.19	1.0337257
26	75549.00	78090.19	1.0336361
27	75723.75	78328.94	1.0344038
28	75893.31	78555.81	1.0350819
29	76062.44	78737.31	1.0351667
30	76228.63	78945.50	1.0356407
31	76390.75	79130.88	1.0358696
32	76547.75	79310.19	1.0360870
33	76698.69	79533.75	1.0369635
34	76842.44	79597.56	1.0358534
35	76982.56	79818.19	1.0368338
36	77123.00	80006.06	1.0373821
37	77261.31	80245.31	1.0386219
38	77395.06	80435.31	1.0392818
39	77521.81	80684.81	1.0408010

TABLE 19

EXPONENTIAL CURVE FIT DATA FOR TEST PLATE 3

CALCULATED	ACTUAL	RATIO	E PRIME
9069.74	9468.67	0.957868	10575213.0
13139.48	17884.73	1.014244	10575213.0
27209.23	26854.66	1.013203	10575213.0
34011.54	33817.88	1.005726	10575213.0
45348.72	45646.88	0.993468	10575213.0
54418.47	54483.50	0.998806	10575213.0
56731.54	59911.28	0.946926	10522496.0
59346.60	64332.78	0.922494	10497184.0
62652.71	68645.25	0.912703	10484752.0
58434.05	70445.75	0.829490	10392200.0
60289.10	72043.38	0.836844	10392200.0
62144.14	72825.81	0.853326	10392200.0
63071.67	73460.06	0.858584	10392200.0
63999.20	74229.13	0.862184	10392200.0
64926.71	74695.19	0.869222	10392200.0
65854.19	75082.88	0.877087	10392200.0
66781.75	75474.88	0.884821	10392200.0
67709.25	75931.75	0.891712	10392200.0
68537.94	76279.50	0.898511	10390752.0
68800.13	76572.69	0.898494	10382200.0
68720.19	76883.38	0.893824	10368976.0
68519.69	77144.50	0.888186	10354576.0
68481.50	77426.13	0.884475	10342480.0
68982.94	77676.06	0.888085	10337569.0
70271.13	77903.19	0.902031	10342912.0
71824.75	78090.19	0.919767	10351440.0
73026.38	78328.94	0.932304	10355488.0
73257.25	78555.81	0.932550	10347384.0
72346.13	78737.31	0.918829	10325248.0
71139.38	78945.50	0.901120	10299504.0
69764.13	79130.88	0.881630	10271608.0
68307.91	79310.19	0.861274	10242504.0
66851.69	79533.75	0.840545	10213144.0
74953.56	79597.56	0.941656	10305160.0
74819.31	79818.19	0.937372	10293536.0
74616.25	80006.06	0.932632	10281336.0
74547.81	80245.31	0.928999	10270680.0
74805.25	80435.31	0.930005	10264048.0
75730.69	80684.81	0.938599	10265504.0

TABLE 20

INVERSE RELATION CURVE FIT DATA FOR PLATE 3

CALCULATED	ACTUAL	RATIO	E PRIME
9071.09	9468.67	0.95801157	10575213.0
18142.20	17884.73	1.01439571	10575213.0
27213.29	26854.66	1.01335430	10575213.0
34016.62	33817.88	1.00587654	10575213.0
45355.50	45646.88	0.99361682	10575213.0
54426.61	54483.50	0.99895573	10575213.0
59424.17	59911.28	0.99186945	10341944.0
63861.27	64332.78	0.99267071	10326528.0
67604.25	68645.25	0.98483503	10103760.0
69534.31	70445.75	0.98706180	10020083.0
70928.06	72043.38	0.98451883	9789744.0
72190.13	72825.81	0.99127108	9536976.0
72756.31	73460.06	0.99042672	9398760.0
73412.19	74229.13	0.98899436	9288192.0
74066.56	74695.19	0.99158412	9180512.0
74423.88	75082.88	0.99122298	8998896.0
75086.06	75474.88	0.99484843	8900240.0
75631.94	75931.75	0.99605155	8774968.0
75895.44	76279.50	0.99496502	8582856.0
76658.88	76572.69	1.00112534	8518536.0
76873.88	76883.38	0.99987638	8323103.0
76864.00	77144.50	0.99636394	8079030.0
77986.38	77426.13	1.00723553	8108317.0
78005.25	77676.06	1.00423717	7879821.0
77873.63	77903.19	0.99962050	7622425.0
79792.94	78090.19	1.02180481	7837308.0
80393.44	78328.94	1.02635670	7750991.0
80933.19	78555.81	1.03026295	7653308.0
81242.88	78737.31	1.03182125	7507544.0
81318.31	78945.50	1.03005600	7314489.0
81212.38	79130.88	1.02630424	7087128.0
80955.38	79310.19	1.02074337	6833040.0
80340.44	79533.75	1.01014233	6509875.0
79633.13	79597.56	1.00044632	6174834.0
82739.31	79818.19	1.03659630	6627019.0
82240.13	80006.06	1.02792358	6340200.0
81510.44	80245.31	1.01576519	6013488.0
80901.56	80435.31	1.00579643	5717715.0
85395.69	80684.81	1.05838585	6427175.0

TABLE 21

DATA FOR TEST PLATE 4

RECORDED DATA

LOAD	STRAIN 1	STRAIN 2	STRAIN 3
3000.00	0.00050000	0.00050000	0.00026250
6000.00	0.00080000	0.00090000	0.00052500
9000.00	0.00125000	0.00130000	0.00078750
12000.00	0.00160000	0.00170000	0.00105000
15000.00	0.00210000	0.00220000	0.00131250
18000.00	0.00250000	0.00260000	0.00157500
21000.00	0.00300000	0.00305000	0.00183750
24000.00	0.00350000	0.00350000	0.00210000
27000.00	0.00390000	0.00400000	0.00236000
30000.00	0.00440000	0.00440000	0.00262500
31000.00	0.00450000	0.00450000	0.00271250
32000.00	0.00460000	0.00470000	0.00280000
33000.00	0.00480000	0.00485000	0.00288000
34000.00	0.00500000	0.00500000	0.00297500
35000.00	0.00510000	0.00510000	0.00306000
36000.00	0.00530000	0.00530000	0.00315000
37000.00	0.00550000	0.00550000	0.00323750
38000.00	0.00560000	0.00560000	0.00332500
39000.00	0.00580000	0.00580000	0.00341250
40000.00	0.00600000	0.00600000	0.00350000
41000.00	0.00610000	0.00610000	0.00358000
42000.00	0.00640000	0.00640000	0.00367500
43000.00	0.00650000	0.00650000	0.00376000
44000.00	0.00670000	0.00670000	0.00385000
45000.00	0.00700000	0.00690000	0.00394000
46000.00	0.00750000	0.00710000	0.00402500
47000.00	0.00745000	0.00730000	0.00411000
48000.00	0.00755000	0.00750000	0.00420000
49000.00	0.00785000	0.00780000	0.00429000
50000.00	0.00800000	0.00800000	0.00437500
51000.00	0.00840000	0.00820000	0.00446250
52000.00	0.00850000	0.00850000	0.00455000
53000.00	0.00880000	0.00880000	0.00463750
54000.00	0.00910000	0.00910000	0.00472500
55000.00	0.00950000	0.00945000	0.00481250
56000.00	0.00980000	0.00970000	0.00490000
57000.00	0.01010000	0.01010000	0.00498750
58000.00	0.01050000	0.01050000	0.00507500
59000.00	0.01080000	0.01075000	0.00516250
60000.00	0.01125000	0.01110000	0.00525000

TABLE 22

DATA FOR TEST PLATE 4

CALCULATED STRESSES

LOAD NO.	STRESS 1	STRESS 2	STRESS 3
1	5177.36	5177.36	2687.92
2	8373.20	9461.90	5441.71
3	13362.65	13927.23	8238.19
4	17322.86	18450.39	11119.55
5	22359.28	23859.94	14068.53
6	26621.02	27540.84	17040.29
7	32213.81	32877.03	19989.95
8	37316.09	37316.09	22859.28
9	40947.87	42236.54	25354.25
10	46686.05	46686.05	27776.06
11	47660.69	47660.69	28624.20
12	48635.28	49609.71	29523.29
13	50584.14	51071.34	30495.06
14	52655.73	52655.73	31858.23
15	54038.90	54038.90	32998.48
16	56311.29	56311.29	33945.03
17	57901.18	57901.18	34814.50
18	58712.77	58712.77	35662.36
19	60786.64	60786.64	36495.01
20	62883.39	62883.39	37316.09
21	63648.68	63648.68	38037.10
22	65782.19	65782.19	38871.38
23	66462.88	66462.88	39623.26
24	67789.00	67789.00	40452.34
25	70157.44	69292.06	41422.80
26	72007.06	70593.13	42592.41
27	71830.44	71306.13	43762.07
28	72185.88	72007.06	44736.47
29	73283.44	73100.13	45613.85
30	73826.44	73826.44	46442.38
31	75002.81	74490.56	47295.21
32	75213.50	75213.50	48148.00
33	75736.25	75736.25	49000.70
34	76207.38	76207.38	49853.32
35	76786.13	76718.56	50705.93
36	77178.65	77048.25	51558.62
37	77545.88	77545.88	52496.78
38	77924.50	77924.50	53685.32
39	78171.88	78131.63	54886.77
40	78519.38	78406.44	55852.53

TABLE 23

DATA FOR TEST PLATE 4

STRESSES AND STRAINS BASED ON LOAD
(NOMINAL AND APPLIED)

LOAD NO.	NOM STRESS	NOM STRAIN	APP STRESS	APP STRAIN
1	3030.30	0.00028655	2777.78	0.00026267
2	6060.61	0.00057310	5555.55	0.00052534
3	9090.91	0.00085964	8333.33	0.00078801
4	12121.21	0.00114619	11111.11	0.00105067
5	15151.52	0.00143274	13888.89	0.00131334
6	18181.82	0.00171929	16666.66	0.00157601
7	21212.12	0.00200583	19444.45	0.00183868
8	24242.42	0.00229238	22222.22	0.00210135
9	27272.73	0.00257893	25000.00	0.00236402
10	30303.03	0.00286548	27777.78	0.00262669
11	31313.13	0.00296099	28703.70	0.00271424
12	32323.23	0.00305651	29629.63	0.00280180
13	33333.33	0.00315202	30555.55	0.00288936
14	34343.43	0.00324754	31481.48	0.00297691
15	35353.54	0.00334306	32407.41	0.00306447
16	36363.64	0.00343857	33333.33	0.00315202
17	37373.74	0.00353409	34259.26	0.00323958
18	38383.84	0.00362960	35185.19	0.00332714
19	39393.94	0.00372512	36111.11	0.00341469
20	40404.04	0.00382064	37037.04	0.00350225
21	41414.14	0.00391615	37962.96	0.00358981
22	42424.24	0.00401166	38888.89	0.00367736
23	43434.34	0.00410718	39814.82	0.00376492
24	44444.45	0.00420270	40740.74	0.00385247
25	45454.55	0.00429821	41666.67	0.00394003
26	46464.65	0.00439373	42592.59	0.00402759
27	47474.75	0.00448925	43518.52	0.00411514
28	48484.85	0.00458476	44444.45	0.00420270
29	49494.95	0.00468028	45370.37	0.00429025
30	50505.05	0.00477579	46296.30	0.00437781
31	51515.15	0.00487131	47222.22	0.00446537
32	52525.25	0.00496683	48148.15	0.00455292
33	53535.36	0.00506234	49074.07	0.00464048
34	54545.46	0.00515786	50000.00	0.00472803
35	55555.55	0.00525337	50925.93	0.00481559
36	56565.66	0.00534889	51851.86	0.00490315
37	57575.76	0.00544440	52777.78	0.00499070
38	58585.86	0.00553992	53703.71	0.00507826
39	59595.96	0.00563544	54629.63	0.00516582
40	60606.06	0.00573095	55555.56	0.00525337

TABLE 24

HEURISTIC DATA FOR PLATE 4

LOAD NO.	HEU STRESS	ACT STRESS	RATIO
1	4476.56	5177.36	1.1565495
2	9102.02	8917.55	0.9797328
3	13934.45	13644.94	0.9792230
4	18334.52	17886.63	0.9496726
5	23544.33	23359.61	0.9921544
6	27552.80	27080.93	0.9828737
7	32684.67	32545.42	0.9957395
8	37021.68	37316.06	1.0079508
9	40968.89	41592.19	1.0152130
10	46057.01	46686.03	1.0136566
11	47465.57	47660.69	1.0041103
12	48873.98	49122.47	1.0050840
13	50282.17	50827.72	1.0108490
14	51690.46	52655.72	1.0186729
15	53445.73	54038.88	1.0110979
16	55368.33	56311.28	1.0170298
17	56709.91	57901.16	1.0210056
18	57836.13	58712.75	1.0151567
19	59034.30	60786.63	1.0296822
20	60562.35	62883.38	1.0383244
21	62186.71	63648.66	1.0235081
22	63420.46	65782.19	1.0372391
23	64483.41	66462.88	1.0306969
24	65498.16	67789.00	1.0349751
25	66484.56	69724.75	1.0487356
26	67446.69	71300.06	1.0571318
27	68399.25	71568.25	1.0463305
28	69640.25	72096.44	1.0352688
29	70524.06	73191.75	1.0378265
30	71045.38	73826.44	1.0391445
31	71551.44	74746.69	1.0446558
32	72059.75	75213.50	1.0437651
33	72583.56	75736.25	1.0434351
34	73114.19	76207.38	1.0423059
35	73641.06	76752.31	1.0422487
36	74152.75	77113.44	1.0399265
37	74597.13	77545.88	1.0395288
38	74961.81	77924.50	1.0395222
39	75265.19	78151.75	1.0383511
40	75525.38	78462.88	1.0388937

TABLE 25

EXPONENTIAL CURVE FIT DATA FOR TEST PLATE 4

CALCULATED	ACTUAL	RATIO	E PRIME
4584.64	5177.36	0.885516	10575213.0
9169.29	8917.35	1.028229	10575213.0
13753.93	13644.94	1.007987	10575213.0
18338.57	17886.63	1.025267	10575213.0
22923.22	23359.61	0.981319	10575213.0
27507.86	27080.93	1.015764	10575213.0
32092.52	32545.42	0.986084	10575213.0
36677.16	37316.06	0.982879	10575213.0
41261.80	41592.19	0.992057	10575213.0
45846.45	46686.03	0.982016	10575213.0
47374.66	47660.69	0.993999	10575213.0
48902.88	49122.47	0.995530	10575213.0
50431.09	50827.72	0.992197	10575213.0
51959.31	52655.72	0.986774	10575213.0
53487.52	54038.88	0.989797	10575213.0
55015.73	56311.28	0.976993	10575213.0
56031.21	57901.16	0.967705	10522496.0
57397.38	58712.75	0.977596	10507792.0
58625.37	60786.63	0.964445	10479984.0
59003.38	62883.38	0.938299	10372112.0
61674.13	63648.66	0.968978	10483976.0
63039.70	65782.19	0.958309	10471360.0
63228.64	66462.88	0.951338	10354336.0
64539.36	67789.00	0.952062	10340200.0
65450.54	69724.75	0.938699	10292632.0
66260.81	71300.06	0.929323	10238184.0
66967.69	71568.25	0.935718	10177384.0
67731.00	72096.44	0.939450	10123208.0
68442.94	73191.75	0.935118	10067256.0
69242.38	73826.44	0.937908	10019912.0
70365.81	74746.69	0.941390	9999456.0
70535.19	75213.50	0.937800	9906848.0
71235.38	75736.25	0.940572	9857280.0
71897.13	76207.38	0.943440	9806472.0
73100.19	76752.31	0.952417	9796960.0
73093.38	77113.44	0.947868	9700280.0
73984.25	77545.88	0.954071	9670808.0
74612.06	77924.50	0.957492	9623456.0
75725.38	78151.75	0.968953	9611528.0
76072.56	78462.88	0.969536	9547296.0

TABLE 26

INVERSE RELATION CURVE FIT DATA FOR PLATE 4

CALCULATED	ACTUAL	RATIO	E PRIME
4584.84	5177.36	0.88555497	10575213.0
9169.68	8917.55	1.02827263	10575213.0
13754.52	13644.94	1.00803089	10575213.0
18339.36	17886.63	1.02531147	10575213.0
22924.21	23359.61	0.98136085	10575213.0
27509.05	27080.93	1.01580811	10575213.0
32093.89	32545.42	0.98612630	10575213.0
36678.74	37316.06	0.98292100	10575213.0
41263.58	41592.19	0.99209934	10575213.0
45848.42	46686.03	0.98205864	10575213.0
47376.71	47660.69	0.99404156	10575213.0
48904.98	49122.47	0.99557257	10575213.0
50433.27	50827.72	0.99223936	10575213.0
51961.55	52655.72	0.98681676	10575213.0
53489.82	54038.88	0.98983967	10575213.0
55018.11	56311.28	0.97703522	10575213.0
56395.03	57901.16	0.97398800	10518536.0
57850.66	58712.75	0.98531687	10493536.0
58965.69	60786.63	0.97004384	10348816.0
60847.13	62883.38	0.96761870	10476816.0
62390.37	63648.66	0.98023075	10484264.0
63473.04	65782.19	0.96489704	10339424.0
64828.28	66462.88	0.97540587	10289160.0
66153.75	67789.00	0.97587734	10231808.0
67288.25	69724.75	0.96505541	10118192.0
68504.69	71300.06	0.96079421	10034208.0
69936.88	71568.25	0.97720528	10017400.0
70660.94	72096.44	0.98008913	9796888.0
71703.56	73191.75	0.97966725	9675440.0
72441.31	73826.44	0.98123807	9474360.0
73274.88	74746.69	0.98030931	9307208.0
73909.38	75213.50	0.98266101	9093440.0
74762.31	75736.25	0.98714036	8944864.0
75571.69	76207.38	0.99165845	8790600.0
75920.81	76752.31	0.98916644	8525984.0
76799.50	77113.44	0.99592888	8401872.0
76863.19	77545.88	0.99119633	8083998.0
77981.38	77924.50	1.00072956	8028986.0
77911.88	78151.75	0.99693060	7696933.0
79768.38	78462.88	1.01663780	7820689.0

TABLE 27

EXPONENTIAL CURVE FIT DATA

PLATE NO.	EXPONENT	CORRELATION
1	5.054	-36.32
2	2.018	-154.5
3	1.095	3.014
4	2.210	6.590

APPENDIX B

FINITE ELEMENT ANALYSIS DATA

TABLE 28

COMPUTER DATA FOR PLATE 1

APPLIED LOAD AND RESULTANT STRESSES
(NOTCH ROOT, APPLIED, AND NOMINAL STRESSES)

LOAD NO.	LOAD (LBS)	NOTCH ROOT	NOMINAL	APPLIED
1	5147.94	18704.00	6651.08	4766.61
2	10295.88	37360.00	13302.16	9533.21
3	15443.81	55968.00	19953.25	14299.82
4	20591.75	76708.00	26604.33	19066.43
5	21607.50	77392.00	27916.66	20006.94
6	22623.24	77680.00	29228.99	20947.45
7	23638.99	77912.00	30541.33	21887.95
8	24654.73	78126.00	31853.66	22828.46
9	25670.48	78412.00	33165.99	23768.96
10	26686.23	78704.00	34478.33	24709.47
11	27701.97	78965.00	35790.66	25649.97
12	28717.72	79216.00	37103.00	26590.48
13	29733.46	79479.00	38415.33	27530.98
14	30749.21	79740.00	39727.66	28471.49
15	31764.96	80006.00	41040.00	29412.00
16	32780.70	80357.00	42352.33	30352.50
17	33796.45	80728.00	43664.66	31293.01
18	34812.20	81082.00	44977.00	32233.52
19	35827.94	81426.00	46289.33	33174.02
20	36843.69	81784.00	47601.66	34114.53
21	37859.43	82354.00	48914.00	35055.03
22	38875.18	82959.00	50226.33	35995.54
23	39890.93	83536.00	51538.66	36936.04
24	40906.67	84097.00	52851.00	37876.55
25	41922.42	84640.00	54163.33	38817.05
26	42938.16	85157.00	55475.66	39757.56
27	43953.91	85756.00	56788.00	40698.07
28	44969.66	86445.00	58100.33	41638.57
29	45985.40	87108.00	59412.66	42579.08
30	47001.15	87756.00	60725.00	43519.58

TABLE 29

COMPUTER DATA FOR PLATE 1

CALCULATED STRAINS

LOAD NO.	NOTCH ROOT	NOMINAL	APPLIED
1	0.00176866	0.00062893	0.00045073
2	0.00353279	0.00125786	0.00090147
3	0.00529237	0.00188679	0.00135220
4	0.00725356	0.00251572	0.00180294
5	0.00784557	0.00263982	0.00189187
6	0.00856628	0.00276392	0.00198081
7	0.00914685	0.00288801	0.00206974
8	0.00968238	0.00301211	0.00215868
9	0.01039809	0.00313620	0.00224761
10	0.01112381	0.00326030	0.00233655
11	0.01178195	0.00338439	0.00242548
12	0.01241007	0.00350849	0.00251442
13	0.01306822	0.00363258	0.00260335
14	0.01372136	0.00375668	0.00269229
15	0.01438702	0.00388077	0.00278122
16	0.01526538	0.00400487	0.00287016
17	0.01619380	0.00412896	0.00295909
18	0.01707967	0.00425306	0.00304803
19	0.01794052	0.00437715	0.00313696
20	0.01883640	0.00450125	0.00322589
21	0.02026280	0.00462534	0.00331483
22	0.02177680	0.00474944	0.00340376
23	0.02322072	0.00487353	0.00349270
24	0.02462460	0.00499763	0.00358163
25	0.02598344	0.00512172	0.00367057
26	0.02727721	0.00524582	0.00375950
27	0.02877619	0.00536991	0.00384844
28	0.03050039	0.00549401	0.00393737
29	0.03215952	0.00561810	0.00402631
30	0.03378112	0.00574220	0.00411524

TABLE 30

COMPUTER DATA FOR PLATE 2

APPLIED LOAD AND RESULTANT STRESSES
(NOTCH ROOT, APPLIED, AND NOMINAL STRESSES)

LOAD NO.	LOAD (LBS)	NOTCH ROOT	NOMINAL	APPLIED
1	5697.71	17654.00	7361.39	5275.66
2	11395.43	35264.00	14722.78	10551.32
3	17093.14	52831.00	22084.16	15826.98
4	22790.86	70585.00	29445.55	21102.65
5	23667.43	73953.00	30578.07	21914.29
6	24544.00	76903.00	31710.59	22725.93
7	25420.57	77315.00	32843.11	23537.57
8	26297.14	77486.00	33975.63	24349.20
9	27173.71	77619.00	35108.15	25160.84
10	28050.28	77780.00	36240.67	25972.48
11	28926.85	77957.00	37373.19	26784.12
12	29803.42	78109.00	38505.71	27595.76
13	30679.99	78268.00	39638.23	28407.40
14	31556.56	78431.00	40770.75	29219.04
15	32433.13	78590.00	41903.27	30030.68
16	33309.70	78815.00	43035.79	30842.32
17	34186.27	79049.00	44168.31	31653.96
18	35062.84	79270.00	45300.83	32465.60
19	35939.41	79477.00	46433.35	33277.23
20	36815.98	79706.00	47565.87	34088.88
21	37692.55	80139.00	48698.39	34900.52
22	38569.13	80521.00	49830.91	35712.15
23	39445.70	80883.00	50963.43	36523.79
24	40322.27	81228.00	52095.95	37335.43
25	41198.84	81559.00	53228.47	38147.07
26	42075.41	81870.00	54360.99	38958.71
27	42951.98	82224.00	55493.51	39770.35
28	43828.55	82695.00	56626.03	40581.99
29	44705.12	83117.00	57758.55	41393.63
30	45581.69	83518.00	58891.07	42205.27

TABLE 31

COMPUTER DATA FOR PLATE 2

CALCULATED STRAINS

LOAD NO.	NOTCH ROOT	NOMINAL	APPLIED
1	0.00166938	0.00069610	0.00049887
2	0.00333459	0.00139220	0.00099774
3	0.00499574	0.00208829	0.00149661
4	0.00667457	0.00278439	0.00199548
5	0.00699305	0.00289149	0.00207223
6	0.00727200	0.00299858	0.00214898
7	0.00765288	0.00310567	0.00222573
8	0.00808080	0.00321276	0.00230248
9	0.00841363	0.00331985	0.00237923
10	0.00881653	0.00342694	0.00245598
11	0.00925947	0.00353404	0.00253273
12	0.00963984	0.00364113	0.00260948
13	0.01003773	0.00374822	0.00268622
14	0.01044563	0.00385531	0.00276297
15	0.01084353	0.00396240	0.00283972
16	0.01140658	0.00406950	0.00291647
17	0.01199216	0.00417659	0.00299322
18	0.01254520	0.00428368	0.00306997
19	0.01306321	0.00439077	0.00314672
20	0.01363628	0.00449786	0.00322347
21	0.01471984	0.00460495	0.00330022
22	0.01567579	0.00471205	0.00337697
23	0.01658168	0.00481914	0.00345372
24	0.01744503	0.00492623	0.00353047
25	0.01827334	0.00503332	0.00360722
26	0.01905161	0.00514041	0.00368396
27	0.01993748	0.00524751	0.00376071
28	0.02111614	0.00535460	0.00383746
29	0.02217218	0.00546169	0.00391421
30	0.02317567	0.00556878	0.00399096

TABLE 32

COMPUTER DATA FOR PLATE 3

APPLIED LOAD AND RESULTANT STRESSES
(NOTCH ROOT, APPLIED, AND NOMINAL STRESSES)

LOAD NO.	LOAD (LBS)	NOTCH ROOT	NOMINAL	APPLIED
1	7497.00	17411.00	8330.00	6941.66
2	14994.00	34771.00	16660.00	13883.33
3	22491.00	52083.00	24990.00	20825.00
4	29988.00	69810.00	33320.00	27766.67
5	30680.03	72000.00	34088.92	28407.43
6	31372.05	73913.00	34857.84	29048.20
7	32064.08	75802.00	35626.76	29688.96
8	32756.11	77200.00	36395.68	30329.73
9	33448.14	77351.00	37164.59	30970.50
10	34140.16	77449.00	37933.52	31611.26
11	34832.19	77549.00	38702.43	32252.03
12	35524.22	77646.00	39471.35	32892.80
13	36216.25	77741.00	40240.27	33533.56
14	36908.27	77833.00	41009.19	34174.33
15	37600.30	77944.00	41778.11	34815.09
16	38292.33	78091.00	42547.03	35455.86
17	38984.36	78208.00	43315.95	36096.63
18	39676.38	78323.00	44084.87	36737.39
19	40368.41	78434.00	44853.79	37378.16
20	41060.44	78542.00	45622.71	38018.93
21	41752.46	78649.00	46391.63	38659.69
22	42444.49	78766.00	47160.55	39300.46
23	43136.52	78880.00	47929.46	39941.22
24	43828.55	78991.00	48698.38	40581.99
25	44520.57	79103.00	49467.30	41222.75
26	45212.60	79218.00	50236.22	41863.52
27	45904.63	79373.00	51005.14	42504.29
28	46596.66	79532.00	51774.06	43145.05
29	47288.68	79686.00	52542.98	43785.82
30	47980.71	79836.00	53311.90	44426.59

TABLE 33

COMPUTER DATA FOR PLATE 3

CALCULATED STRAINS

LOAD NO.	NOTCH ROOT	NOMINAL	APPLIED
1	0.00164640	0.00078769	0.00065641
2	0.00323797	0.00157538	0.00131282
3	0.00492501	0.00236307	0.00196923
4	0.00660129	0.00315076	0.00262564
5	0.00680837	0.00322347	0.00268623
6	0.00698927	0.00329618	0.00274682
7	0.00716789	0.00336889	0.00280741
8	0.00736510	0.00344160	0.00286800
9	0.00774297	0.00351431	0.00292859
10	0.00798821	0.00358702	0.00298918
11	0.00823846	0.00365973	0.00304978
12	0.00848120	0.00373244	0.00311037
13	0.00871893	0.00380515	0.00317096
14	0.00894916	0.00387786	0.00323155
15	0.00922693	0.00395057	0.00329214
16	0.00959479	0.00402328	0.00335273
17	0.00988758	0.00409599	0.00341332
18	0.01017537	0.00416870	0.00347391
19	0.01045314	0.00424141	0.00353451
20	0.01072341	0.00431411	0.00359510
21	0.01099117	0.00438682	0.00365569
22	0.01128396	0.00445953	0.00371628
23	0.01156924	0.00453224	0.00377687
24	0.01184702	0.00460495	0.00383746
25	0.01212729	0.00467766	0.00389805
26	0.01241507	0.00475037	0.00395864
27	0.01280295	0.00482308	0.00401923
28	0.01320085	0.00489579	0.00407983
29	0.01358623	0.00496850	0.00414042
30	0.01396160	0.00504121	0.00420101

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TABLE 34

COMPUTER DATA FOR PLATE 4

APPLIED LOAD AND RESULTANT STRESSES
(NOTCH ROOT, APPLIED, AND NOMINAL STRESSES)

LOAD NO.	LOAD (LBS)	NOTCH ROOT	NOMINAL	APPLIED
1	11495.39	17350.00	11611.51	10643.88
2	22990.79	34645.00	23223.02	21287.77
3	34486.18	51887.00	34834.53	31931.65
4	45981.58	69074.00	46446.04	42575.54
5	46527.51	69889.00	46997.49	43081.03
6	47073.45	70704.00	47548.93	43586.52
7	47619.38	71519.00	48100.38	44092.02
8	48165.31	72334.00	48651.83	44597.51
9	48711.25	73148.00	49203.28	45103.01
10	49257.18	74026.00	49754.73	45608.50
11	49803.11	75000.00	50306.18	46114.00
12	50349.05	75905.00	50857.63	46619.49
13	50894.98	76797.00	51409.07	47124.98
14	51440.91	77198.00	51960.52	47630.48
15	51986.85	77247.00	52511.97	48135.97
16	52532.78	77285.00	53063.42	48641.46
17	53078.71	77323.00	53614.86	49146.96
18	53624.65	77361.00	54166.31	49652.45
19	54170.58	77408.00	54717.76	50157.95
20	54716.52	77456.00	55269.21	50663.44
21	55262.45	77499.00	55820.66	51168.94
22	55808.38	77542.00	56372.11	51674.43
23	56354.32	77588.00	56923.55	52179.93
24	56900.25	77633.00	57475.00	52685.42
25	57446.18	77677.00	58026.45	53190.91
26	57992.12	77720.00	58577.90	53696.41
27	58538.05	77766.00	59129.34	54201.90
28	59083.98	77832.00	59680.79	54707.39
29	59629.92	77898.00	60232.24	55212.89
30	60175.85	77960.00	60783.69	55718.38

TABLE 35

COMPUTER DATA FOR PLATE 4

CALCULATED STRAINS

LOAD NO.	NOTCH ROOT	NOMINAL	APPLIED
1	0.00164063	0.00109799	0.00100649
2	0.00327606	0.00219599	0.00201299
3	0.00490647	0.00329398	0.00301948
4	0.00653169	0.00439197	0.00402597
5	0.00660875	0.00444411	0.00407377
6	0.00668582	0.00449626	0.00412157
7	0.00676289	0.00454840	0.00416937
8	0.00683995	0.00460055	0.00421717
9	0.00691693	0.00465270	0.00426497
10	0.00699955	0.00470484	0.00431277
11	0.00709205	0.00475699	0.00436057
12	0.00717763	0.00480913	0.00440837
13	0.00726198	0.00486128	0.00445617
14	0.00736009	0.00491342	0.00450397
15	0.00748271	0.00496557	0.00455177
16	0.00757781	0.00501771	0.00459957
17	0.00767290	0.00506986	0.00464737
18	0.00776800	0.00512201	0.00469517
19	0.00788561	0.00517415	0.00474297
20	0.00800573	0.00522630	0.00479077
21	0.00811334	0.00527844	0.00483857
22	0.00822094	0.00533058	0.00488637
23	0.00833606	0.00538273	0.00493417
24	0.00844867	0.00543488	0.00498197
25	0.00855878	0.00548702	0.00502977
26	0.00866638	0.00553917	0.00507757
27	0.00878149	0.00559131	0.00512537
28	0.00894666	0.00564346	0.00517317
29	0.00911182	0.00569560	0.00522097
30	0.00926697	0.00574775	0.00526877

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